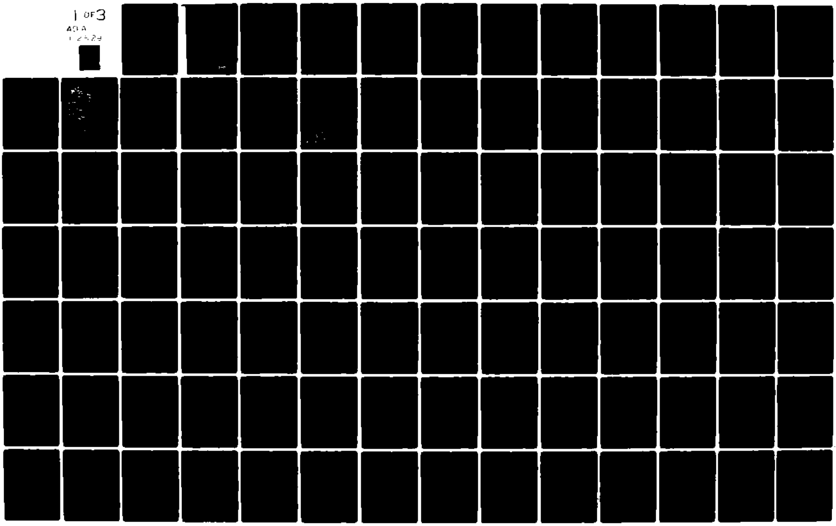
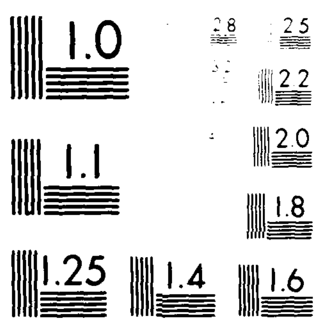
AD-A112 529 FUGRO NATIONAL INC LONG BEACH CA F/G 8/7
MX SITING INVESTIGATION. PRELIMINARY GEOTECHNICAL INVESTIGATION--ETC(U)
MAR 81 F04704-80-C-0006
UNCLASSIFIED FN-TR-45-VOL-1 NL

1 OF 3
AD A
112529




1.0
2.8
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

PHOTOGRAPH THIS SHEET

AD A112 529

DTIC ACCESSION NUMBER

II

LEVEL

1

INVENTORY

FN-TR-45-I

DOCUMENT IDENTIFICATION

This document has been approved for public release and sale; its distribution is unlimited.

DISTRIBUTION STATEMENT

ACCESSION FOR		
NTIS	GRA&I	☒
DTIC	TAB	☐
UNANNOUNCED		☐
JUSTIFICATION		
BY		
DISTRIBUTION /		
AVAILABILITY CODES		
DIST	AVAIL AND/OR SPECIAL	
A		

DISTRIBUTION STAMP

DTIC ELECTE MAR 25 1982

S E D

DATE ACCESSIONED

DTIC COPY INSPECTED 2

8 ... 5

DATE RECEIVED IN DTIC

PHOTOGRAPH THIS SHEET AND RETURN TO DTIC-DDA-2

DTIC FORM OCT 79 70A

DOCUMENT PROCESSING SHEET

MX SITING INVESTIGATION
GEOTECHNICAL EVALUATION

PRELIMINARY GEOTECHNICAL INVESTIGATION PROPOSED OPERATIONAL BASE SITE BERYL, UTAH

VOLUME I - SYNTHESIS

PREPARED FOR
BALLISTIC MISSILE OFFICE (BMO)
NORTON AIR FORCE BASE, CALIFORNIA

FUGRO NATIONAL, INC.
Consulting Engineers and Geologists

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: FN-TR-45-I
2. GOVT ACCESSION NO.:
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): Preliminary Geotechnical Investigation - proposed operational Base site, Beryl, Utah Volume I - Synthesis
5. TYPE OF REPORT & PERIOD COVERED: Final
6. PERFORMING ORG. REPORT NUMBER: FN-TR-45
7. AUTHOR(s): Fugro National
8. CONTRACT OR GRANT NUMBER(s): F04704-80-C-0006
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Ertec Western Inc (formerly Fugro National) P.O. Box 7765 Long Beach Ca 90807
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 64312 F
11. CONTROLLING OFFICE NAME AND ADDRESS: U.S. Department of the Air Force Space and Missile Systems Organization [illegible] AFS Ca 90009 (SAMSO)
12. REPORT DATE: 27 Mar 81
13. NUMBER OF PAGES: 97
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):
15. SECURITY CLASS. (of this report):
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:
16. DISTRIBUTION STATEMENT (of this Report): Distribution Unlimited
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report): Distribution Unlimited
18. SUPPLEMENTARY NOTES:

19. KEY WORDS (Continue on reverse side if necessary and identify by block number) ~~Siting criteria,~~ ~~Assumptions for operational Base structures,~~ ~~Geographic + cultural conditions,~~ ~~Geotechnical conditions,~~ floods, [illegible] Geology, boring, trench, test pit, cone penetro[illegible], Seismic refraction, electrical resistivity, bedrock, [illegible] faults

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
This report presents the results of a preliminary geotechn[illegible] evaluation of the proposed Operational Base site near Beryl, Utah. The purpose of this study was to assess the geological, geophysical, & soils engineering data & to present recommendations regarding site suitability, foundations for various facilities, construction considerations, & aggregate resources.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

FN-TR-45

MX SITING INVESTIGATION
GEOTECHNICAL EVALUATION

PRELIMINARY GEOTECHNICAL INVESTIGATION
PROPOSED OPERATIONAL BASE SITE
BERYL, UTAH

VOLUME I - SYNTHESIS

Prepared for:

U.S. Department of the Air Force
Ballistic Missile Office
Norton Air Force Base, California 92409

Prepared by:

Fugro National, Inc.
3777 Long Beach Boulevard
Long Beach, California 90807

27 March 1981

FUGRO NATIONAL, INC.

FOREWORD

This report was prepared for the Department of the Air Force, Ballistic Missile Office (BMO), in compliance with Contract No. F04704-80-C-0006, CDRL Item 004A6. It contains a preliminary geotechnical evaluation of the proposed Operational Base (OB) site near Beryl, Utah. The Operational Base will support the MX Land Mobile Advanced ICBM System in Nevada and Utah. This report presents geological, geophysical, and soils engineering data as well as recommendations regarding site suitability, preliminary conclusions regarding foundations for various facilities, construction considerations, and aggregate resources.

Concurrent with the study reported herein, one other proposed Operational Base site in Utah (Milford), and one in Nevada (Coyote Spring Valley) have been investigated for the same purpose. Reports on the Coyote Spring and Milford sites were issued on 23 December 1980 and 20 February 1981, respectively. Other studies in progress for the same three Operational Base sites are water resources, environmental, mineral surveys, and topographic mapping. The results of these studies will be

Volume I of this report is a synthesis of the data obtained during the study. Volume II is a detailed compilation of the data generated and used in this investigation.

TABLE OF CONTENTS

Page

FOREWORD i

EXECUTIVE SUMMARY vii

1.0 INTRODUCTION 1

2.0 SITING CRITERIA AND ASSUMPTIONS FOR OPERATIONAL BASE STRUCTURES 4

2.1 Siting Criteria 4
2.2 Assumptions for Operational Base Structures 6

3.0 SCOPE 8

3.1 Review of Existing Data 8
3.2 Field Investigation 8
3.2.1 Geologic Mapping 11
3.2.2 Borings 11
3.2.3 Trenches and Test Pits 11
3.2.4 Cone Penetrometer Tests (CPTs) 12
3.2.5 Seismic Refraction Surveys 12
3.2.6 Electrical Resistivity Surveys 12
3.3 Laboratory Testing 12
3.4 Analyses, Conclusions, and Recommendations 12

4.0 GEOGRAPHIC AND CULTURAL CONDITIONS 14

4.1 Location 14
4.2 Cultural Features 14
4.3 Land Status 15

5.0 GEOTECHNICAL CONDITIONS 17

5.1 Regional Geologic Setting 17
5.2 Site Geologic Units 17
5.2.1 Bedrock 18
5.2.2 Older-Age Alluvial Fan Deposits (A5o) 19
5.2.3 Intermediate-Age Alluvial Fan Deposits (A5i) 20
5.2.4 Mixed Pleistocene Lake Deposits with Young Alluvial Fan (A4o/A5y) and Eolian Deposits (A4o/A3s) 21
5.2.5 Young Alluvial Fan Deposits (A5y) 22
5.2.6 Young Fluvial Deposits (A1) 22
5.2.7 Eolian Deposits (A3d, A3s, A3s/A4o) 23
5.3 Subsurface Conditions 24
5.3.1 Thickness of the Basin-Fill Deposits 24
5.3.2 Subsurface Soils 24

TABLE OF CONTENTS (Cont.)

		Page
	5.3.3 Depth to Rock	25
	5.3.4 Depth to Water	27
	5.4 Terrain and Drainage	28
	5.5 Geologic Hazards	29
	5.5.1 Flooding	30
	5.5.2 Faults and Seismicity	31
	5.5.3 Subsidence	32
	5.5.4 Sand Dunes and Sheet Sands	33
	5.5.5 Rockfall	33
6.0	DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS	34
	6.1 Site Suitability	34
	6.1.1 Depth to Rock	34
	6.1.2 Depth to Water	34
	6.1.3 Terrain	36
	6.1.4 Geologic Hazards	36
	6.2 Foundation Considerations	40
	6.2.1 Geotechnical Properties of Subsurface Soils	40
	6.2.2 Foundation Recommendations	45
	6.3 Roads and Runway	48
	6.3.1 Roads	48
	6.3.2 Runway	49
	6.4 Slope Stability	49
	6.5 Construction Considerations	51
	6.6 Aggregate Sources	52
7.0	RECOMMENDATIONS FOR FUTURE STUDIES	56
	7.1 Flooding Potential	56
	7.2 Faults and Seismicity	56
	7.3 Subsidence	57
	7.4 Sand Dunes	57
	7.5 Foundation Design	58
	7.6 Aggregate Resources	58
8.0	REFERENCES CITED	60

APPENDIX

A1.0	GLOSSARY OF TERMS	A-1

TABLE OF CONTENTS (Cont.)
APPENDIX (Cont.)

Page

A2.0 ENGINEERING GEOLOGIC PROCEDURES A-11

A2.1 Review of Existing Data A-11
A2.2 Geologic Reconnaissance A-11

A3.0 GEOPHYSICAL PROCEDURES A-13

A3.1 Seismic Refraction Surveys A-13
A3.1.1 Instruments A-13
A3.1.2 Field Procedures A-13
A3.1.3 Data Reduction A-15
A3.2 Electrical Resistivity Surveys A-16
A3.2.1 Instruments A-16
A3.2.2 Field Procedures A-16
A3.2.3 Data Reduction A-18

A4.0 ENGINEERING PROCEDURES A-19

A4.1 Borings A-19
A4.1.1 Drilling Techniques A-19
A4.1.2 Method of Sampling A-19
A4.1.3 Logging A-22
A4.1.4 Sample Storage and Transportation A-23
A4.1.5 Ground-Water Observation Wells A-23
A4.2 Trenches and Test Pits A-24
A4.2.1 Excavation Equipment A-24
A4.2.2 Method of Excavation A-24
A4.2.3 Sampling A-24
A4.2.4 Logging A-25
A4.3 Cone Penetrometer Tests A-26
A4.3.1 Equipment A-26
A4.3.2 Test Method A-27
A4.4 Field Visual Soil Classification A-27
A4.4.1 General A-27
A4.4.2 Soil Description A-27
A4.5 Laboratory Tests A-34
A4.6 Data Reduction A-35

LIST OF FIGURES

1.0 INTRODUCTION

1-1 Location Map, Operational Base Site, Beryl, Utah .. 2

TABLE OF CONTENTS (Cont.)
LIST OF FIGURES (Cont.)

Page

2.0 SITING CRITERIA AND ASSUMPTION FOR OPERATIONAL BASE STRUCTURES

2-1 Proposed Activity Center Layout, Operational Base Site, Beryl, Utah 5

6.0 DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

6-1 Soil Profile 1-1' - Operational Base Site, Beryl, Utah 42
6-2 Soil Profile 2-2' - Operational Base Site, Beryl, Utah 43
6-3 CBR Values for Sand, Operational Base Site, Beryl, Utah 50

A3.0 GEOPHYSICAL PROCEDURES

A3-1 Spread Configuration, Seismic Refraction Line, Operational Base Site, Beryl, Utah A-14
A3-2 Schlumberger Array Electrical Resistivity Soundings A-17

LIST OF TABLES

3.0 SCOPE

3-1 Field Techniques, Operational Base Site, Beryl, Utah 9
3-2 Scope of Activities, Operational Base Site, Beryl, Utah 10

5.0 GEOTECHNICAL CONDITIONS

5-1 Physical Properties of Subsoils, Operational Base Site , Beryl, Utah 26

6.0 DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

6-1 Summary of Geotechnical Conditions, Operational Base Site, Beryl, Utah 35
6-2 Characteristics of Subsurface Soils, Operational Base Site, Beryl, Utah 44

TABLE OF CONTENTS (Cont.)
LIST OF TABLES (Cont.)

Page

A4.0 ENGINEERING PROCEDURES

A4-1 Unified Soil Classification System A-28

LIST OF DRAWINGS

4.0 GEOGRAPHIC AND CULTURAL CONDITIONS

4-1 Land Status Map, Operational Base Site, Beryl, Utah — At End of Section

5.0 GEOTECHNICAL CONDITIONS

5-1 Geologic Map, Operational Base Site, Beryl, Utah
5-2 Depth to Water Map, Operational Base Site, Beryl, Utah
5-3 Terrain Map, Operational Base Site, Beryl, Utah — At End of Section
5-4 Geologic Hazards Map, Operational Base Site, Beryl, Utah
5-5 Epicenter Location Map, Operational Base Site, Beryl, Utah

EXECUTIVE SUMMARY

Preliminary geotechnical investigations were completed at the proposed Operational Base (OB) site near Beryl, Utah. The conclusions and recommendations resulting from these studies are as follows:

1. Depth to Rock - Rock is not expected to occur within 150 feet (46 m) of the surface in the proposed Main Operational Base, Designated Assembly Area, and all but the grade test track of the Operational Base Test and Training Site. Rock is exposed at the surface in northern portions of the proposed Base Housing and in the Operational Base Test and Training site grade test track area. Southern portions of the Base Housing area have depths to rock greater than 50 feet (15 m).

2. Depth to Water - Ground water within 50 feet (15 m) of the ground surface is not anticipated below any of the proposed activity centers. Additionally, the depth to ground water is greater than 150 feet (46 m) beneath the Designated Assembly and Base Housing areas and the northwestern portion of the Main Operational Base area.

3. Terrain - Adverse terrain and steep surface slopes (greater than 10 percent) occur only in the proposed Base Housing area. Additionally, steep surface slopes occur along the western mountain front and in the walls of major washes.

4. Flooding - The potential for major flooding is relatively low in the general site area. Flood-prone areas are present in the western portion of the Main Operational Base and in a small area in the central portion of the Designated Assembly Area. Flooding would be limited to the floodplains of some Younger-age alluvial fans and to the major washes in the intermediate-age alluvial fans. It is likely that conventional flood control methods would be effective in controlling any flood hazard. The extent and precise locations of potential flooding and ponding should be determined in subsequent studies.

5. Faults - Active and potentially active faults occur east of the site but do not trend through any of the proposed activity centers. Historic seismicity in the site area has been low; however, earthquakes of magnitudes of 7.5 have been recorded in the region. The potential for fault rupture and earthquake hazards should be evaluated in future studies.

6. Subsidence - No subsidence features due to ground-water withdrawal (i.e., ground fissures) were observed in the

vicinity of the proposed site. The potential for future fissure development is interpreted to be low.

7. Sand Dunes - Sand dunes and sheet sand deposits occur south of the proposed site area. Presently, these deposits are mostly stable. The potential for reactivation of the sand dunes from surface disruptions related to site construction and other related activities should be evaluated in future studies.

8. Rockfall - The potential for rockfall hazards appears to be extremely low within the proposed site area.

9. Foundations - The subsurface soils in the activity center areas consist predominantly of medium-dense to very dense gravel and sand. In the extreme southern corner of the Main Operational Base, the gravel and sand are interbedded with firm to hard sandy silt, silt, silty clay, and clay. The subsurface soils are considered to be fair to excellent foundation-bearing materials. It is expected that all structures can be supported by a system of shallow-spread or continuous footings.

10. Roads and Runway - Most of the roads will traverse alluvial fan deposits consisting mainly of gravel and sand. The gravel will provide good to excellent subgrade support, and the sand will provide fair to good subgrade support. The runway trends through silty sand deposits that will provide fair to good subgrade support.

11. Slope Stability - Natural slopes are in a stable condition. Temporary excavations in the granular alluvial deposits can be made with slopes between 1/2:1 (horizontal:vertical) in the cemented gravelly materials to 1-1/2:1 in the cleaner sandy deposits.

12. Construction Considerations - Conventional equipment can be used for excavation and compaction in the top 5 feet (1.5 m) in all areas except portions of the Base Housing area. In the Base Housing area where Stage III and IV caliche cementation and shallow rock exist, ripping and/or blasting may be required for excavation. Sulfate attack of lake sediments on concrete will have to be taken into consideration in design of concrete elements exposed to the soil. Frost attack, especially in the silty sands, sandy silts, and silts, should be considered for the design of the roads, runway, and foundations.

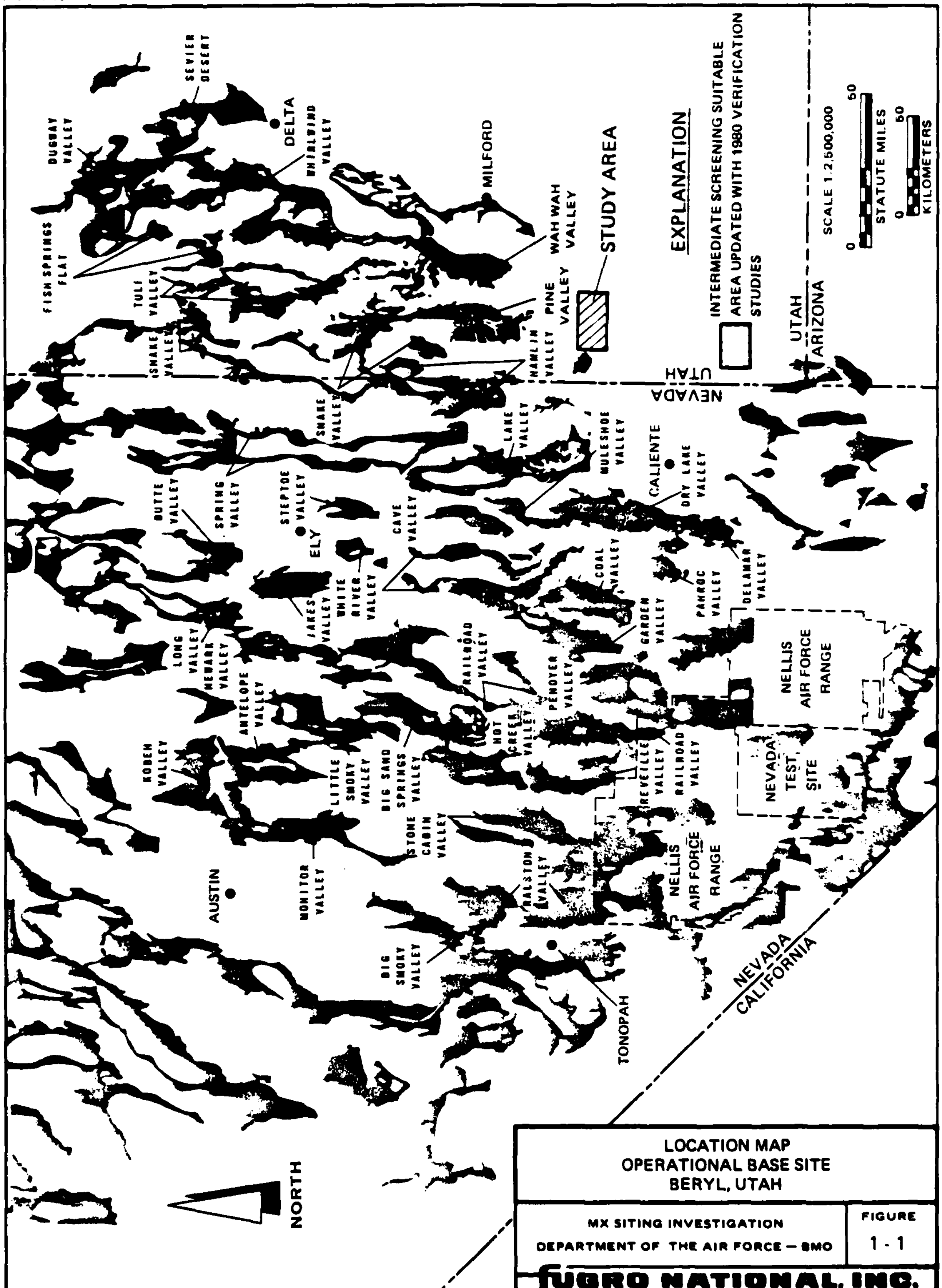
1.0 INTRODUCTION

This report presents the results of a preliminary geotechnical evaluation of the proposed Operational Base (OB) site near Beryl, Utah (Figure 1-1). The purpose of this study was to assess the geological, geophysical, and soils engineering data and to present recommendations regarding site suitability, foundations for various facilities, construction considerations, and aggregate resources.

Our previous report, "Proposed Operational Base Site, Escalante Desert, Beryl Area, Utah," submitted 13 June 1980, included discussions on water supply, land ownership, existing and proposed transportation systems, and terrain and geotechnical conditions. No field work was conducted for that initial study. Two conceptual layouts were presented in the 1980 report for the three major activity centers; i.e., the Main Operational Base (MOB), the Designated Assembly Area (DAA), and the Operational Base Test and Training Site (OBTS). Subsequently, there have been a series of meetings and discussions concerning the location of activity centers within the siting areas.

For the present site-specific investigation, the preferred conceptual layouts (as described in Section 2.0) were developed by a working group on Operational Base siting composed of personnel from SAC, AFRCE, BMO, Fugro National, TRW, Martin Marietta, COE, and the Ralph M. Parsons Company. The geotechnical siting criteria and exclusions which formed a baseline for the present

FN-TR-45



LOCATION MAP
OPERATIONAL BASE SITE
BERYL, UTAH

MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE — BMO	FIGURE 1 - 1

FUGRO NATIONAL, INC.

20 MAR 81

study are derived from the document entitled "Siting Criteria for MX Operating Bases, 10 November 1980."

The present report is more detailed than our prior report and is the result of a thorough review of available geotechnical data and preliminary field studies in the vicinity of the proposed site. This report contains two volumes: Volume I is a synthesis of the data with conclusions and recommendations, and Volume II is a compilation of the data. This report is intended to be utilized by the architect and engineer for the preliminary layout of facilities within the various activity centers and for preliminary foundation-design considerations.

The objectives of this study have been to:

- Identify the geologic units;
- Characterize the geologic units and describe the physical and engineering properties of the subsoils in the activity center areas;
- Determine the subsurface conditions and estimate depths to rock and water;
- Identify adverse terrain conditions;
- Identify geologic hazards including flooding, faults and seismicity, subsidence, sand dunes, and rock-falls;
- Develop preliminary foundation design recommendations for the activity center areas and general construction considerations; and
- Identify potential aggregate sources.

2.0 SITING CRITERIA AND ASSUMPTIONS FOR OPERATIONAL BASE STRUCTURES

Conceptually, the proposed Operational Base consists of four main activity centers (Figure 2-1). Their names and approximate areas are as follows:

Activity Center	Approximate Area acres (hectares)
Main Operational Base (MOB)	1800 (700)
Designated Assembly Area (DAA)	1800 (700)
Operational Base Test and Training Site (OBTS)	2200 (900)
Base Housing (BH)	2700 (1100)

The proposed layouts of these centers at the Beryl site (Figure 2-1) were developed by the Operational Base working group on 20 August 1980.

2.1 SITING CRITERIA

The Operational Base layout for the proposed Beryl site generally follows the criteria set out in the draft BMO document "MX Siting Criteria for MX Operating Bases, 10 November 1980." In this document, guidelines for siting and exclusion are also provided. Those guidelines relevant to the present geotechnical investigation are presented below.

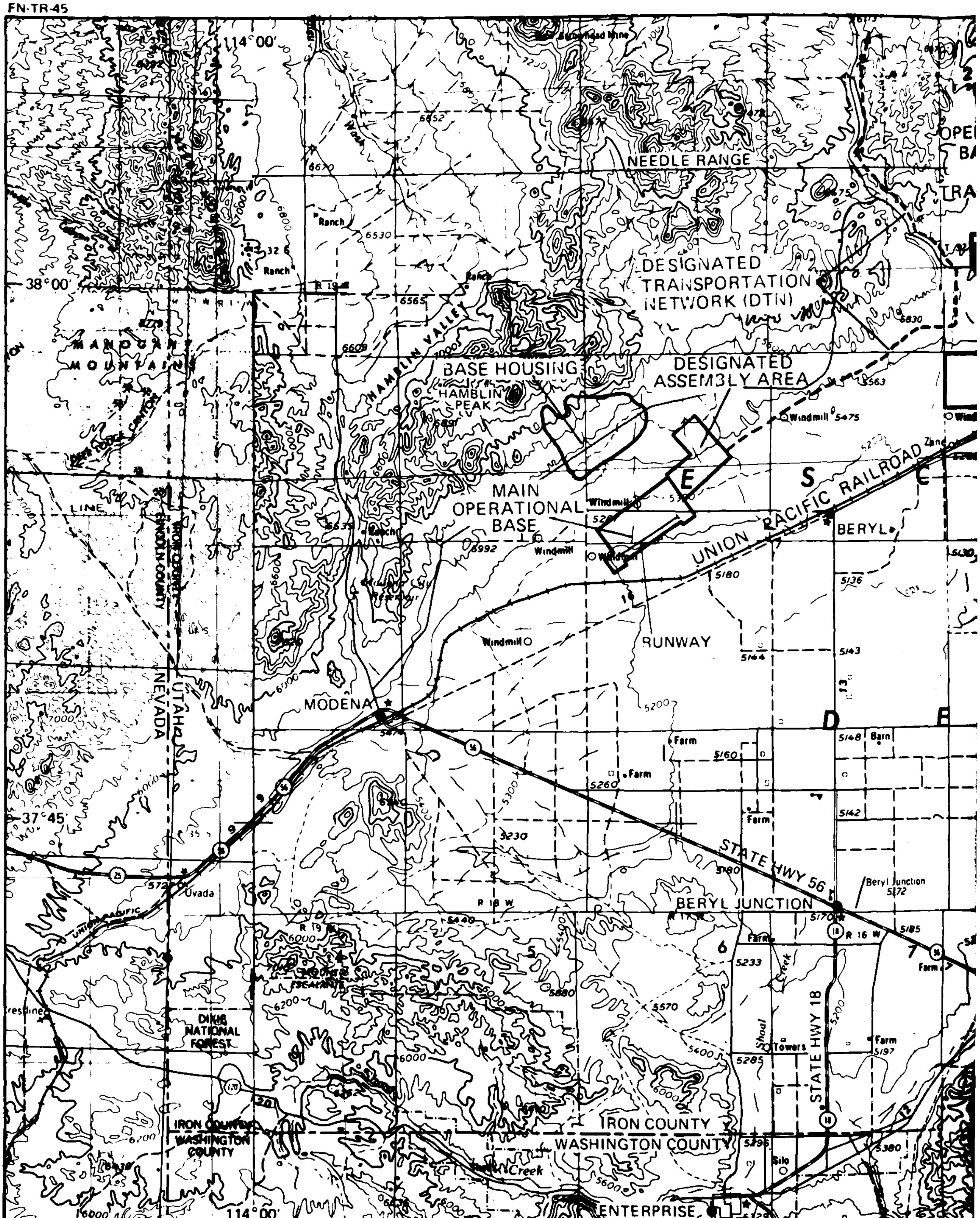
Desirable Geotechnical Features

- Suitable soil for building and landscaping; and
- Avoidance of active and potentially active fault zones.

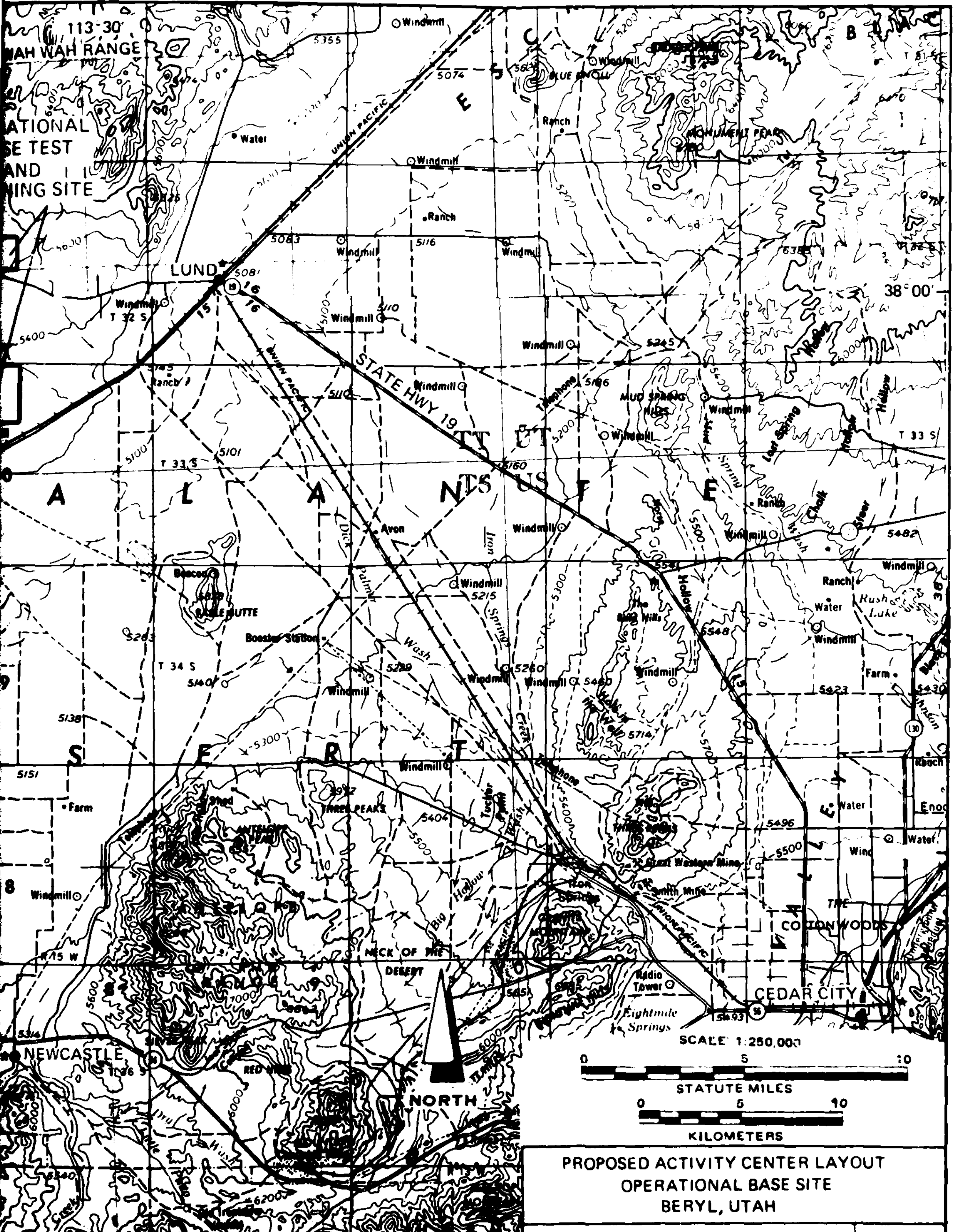
Geotechnical Exclusions

- Areas having rock and water within 50 feet (15 m) of the surface except base technical and housing areas;

FN-TR-45



20 MAR 81



PROPOSED ACTIVITY CENTER LAYOUT
OPERATIONAL BASE SITE
BERYL, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE BMO

FIGURE 2-1

FUGRO NATIONAL, INC.

- Surface grades (for DAA/OBTS/Training and Airfield) as follows

  - Nominal surface grade of greater than five percent;
  - Local grade greater than 10 percent measured over a 1000-foot (305-m) length;
  - More than two 10-foot (3-m) deep drainage crossings per 1000 feet (305 m); and

- Areas of surface water including all significant lakes, reservoirs, swamps, perennial drainages, and playas subject to flooding.

2.2 ASSUMPTIONS FOR OPERATIONAL BASE STRUCTURES

Proposed structures and the estimated column loads, identified in each activity center, are listed below. For discussion purposes, the estimated column loads are categorized into light (less than 50 kips [23 tonnes]), medium (50 to 200 kips [23 to 91 tonnes]), and high (greater than 200 kips [91 tonnes]).

Structures in MOB	Estimated Column Load High (H), Medium (M), or Light (L)
Office (office space for 800 personnel, computer center, and dining space for 1000 people)	M
Shop	L
Communication Tower	H
Fuel Tank	not applicable
Storage Silo	H
Warehouse	L to M
Fire Station	L
Vehicle Maintenance Facility	L
Airport Facility	M
Runway (12,000 feet [3658 m] long)	not applicable
Marshalling Yard	not applicable
Structures in DAA	
Missile Assembly Building (150-ton [136-tonne] bridge crane)	H
Heavy Vehicles Assembly Facility (15-ton [14-tonne] bridge crane)	M

Launcher Assembly Building	M
Launcher Integration Building	M
Stage Storage Area (earth-covered structure, 10-ton [9-tonne] overhead crane)	M
Weapon Storage Area	M
Missile Storage Area	M
Warehouse	L to M
Office	L
Laboratory (electronic equipment)	L
Shop	L

Structures in OBTS

Cluster Maintenance Facility Storage	M
Office	L
Laboratory	L
Shop	L

Structures in BH

Residential Houses	L
Apartments	L
Community Center	M
Hospital	M
Recreation Center	M
School	M

These assumptions regarding column loads were used in planning the geotechnical investigations described herein. Additionally, they are the basis for the discussion of Foundation Considerations in Section 6.2.

All the structures except the Missile Assembly Building (MAB) have been assumed to have the lowest floor level at final grade. Only the deeper part of the MAB will have lowest floor level at 50 feet (15 m) below grade.

3.0 SCOPE

The scope of the study consisted of the following:

- Review of existing data;
- Field investigations;
- Laboratory testing on selected samples recovered from the borings, trenches, and test pits; and
- Analyses of the results of the field and laboratory investigations and the subsequent discussions, conclusions, and recommendations.

3.1 REVIEW OF EXISTING DATA

Prior to the geotechnical field activities, existing data were reviewed. The existing data included the results of the previous investigation by Fugro National, Inc. (report dated 13 June 1980, FN-TR-35), other published literature, land-status conditions, and results of geologic investigations in the general vicinity of the sites published by the Utah Geological and Mineral Survey and the U.S. Geological Survey.

3.2 FIELD INVESTIGATION

The field investigation performed in October and November 1980 consisted of geologic mapping, exploratory borings, trenches, test pits, cone penetrometer tests, and geophysical (seismic refraction and electrical resistivity) surveys. The different techniques used in the field investigation are outlined in Table 3-1. Detailed procedures for geologic, geophysical, and engineering activities are included in Sections A2.0, A3.0, and A4.0 of Appendix A, respectively. Table 3-2 lists the types and numbers of the field activities performed.

OBJECTIVES → **VERIFICATION OF SUITABLE AREA FO**

DATA FOR EVALUATIONS → TERRAIN PARAMETERS | GEOLOGIC HAZARDS

FIELD TECHNIQUES AND APPLICATIONS →

TERRAIN PARAMETERS

Geologic mapping

- Identification and limits of areas with slopes greater than 5% and 10% grade

GEOLOGIC HAZARDS

Geologic mapping

- Evaluation of flooding potential
- Identification of faults and lineaments
- Subsidence potential
- Evaluation of dune and sheet sand stability
- Evaluation of rockfall potential

AREA FOR ACTIVITY CENTER LAYOUTS

CHA

S

DEPTH TO ROCK

DEPTH TO GROUND WATER

EXTENT AND CHARACTERISTICS OF SOILS

GEOPHYS PROPERT

DEPTH TO ROCK

Geologic mapping

- Surface limits of rock
- Depth to rock from topographic and geologic interpretation
- Geomorphic expression and erosion history

Seismic refraction surveys

- Subsurface projection of rock limits
- Delineation of high velocity layers from p-wave velocities (> 7000 fps)

Borings

- Occurrence of rock

Existing data

- Published literature

DEPTH TO GROUND WATER

Borings

- *Occurrence of ground water*

Electrical resistivity/ seismic refraction surveys

- Provide supplemental data to support presence or *absence of ground water*

Existing Data

- *Published literature*

EXTENT AND CHARACTERISTICS OF SOILS

Geologic mapping

- Extent of surficial soil units
- Surficial soil types

Borings

- Identification of subsurface soil types
- In situ soil density and consistency
- Samples for laboratory testing

Trenches and test pits

- Identification of surface and subsurface soil types
- Degree of induration and cementation of soils
- In situ moisture and density of soil
- Samples for laboratory testing

Cone penetrometer tests

- In situ soil strength

Laboratory tests

- Physical properties
- Engineering properties – shear strength, compressibility
- Chemical properties

GEOPHYS PROPERT

Seismic refraction

- Compressional wave

Electrical resis surveys

- Electrical conducti
- Layering of soil

2

CHARACTERISTICS OF BASIN FILL → **PRELIMINARY GEOTECH CONSIDERATIONS A RECOMMENDATIO**

GEOPHYSICAL PROPERTIES

Seismic refraction surveys

- Compressional wave velocities

Electrical resistivity surveys

- Electrical conductivity of soils
- Layering of soil

ROAD AND RUNWAY DESIGN DATA

Trenches and test pits

- Identification of soil types
- In situ soil density and moisture
- Thickness of low strength surficial soil

Cone penetrometer tests

- In situ soil strength

Laboratory tests

- Physical properties
- Compaction and CBR data
- Suitability of soils for use as road subgrade, subbase or base

Existing data

- Suitability of soils for use as road subgrade, subbase, or base
- Behavior of compacted soils

EXCAVATABILITY AND STABILITY

Borings

- Subsurface soil types
- Presence of cobbles and boulders
- In situ density of subsurface soils
- Stability of vertical walls

Trenches and test pits

- Subsurface soil types
- Subsurface soil density and cementation
- Stability of vertical walls
- Presence of cobbles and boulders

Laboratory tests

- Physical properties
- Engineering properties

Geologic mapping

- Distribution of geologic units

Seismic refraction surveys

- Excavatability

FIELD TECH
OPERATIONAL
BERYL, U

MX SITING INVESTIGA
DEPARTMENT OF THE AIR FO
UGRO NAT

PRELIMINARY GEOTECHNICAL CONSIDERATIONS AND RECOMMENDATIONS

FIELD TECHNIQUES
OPERATIONAL BASE SITE
BERYL, UTAH

MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE — BMO	TABLE 3-1

FUGRO NATIONAL, INC.

4

GEOLOGY AND GEOPHYSICS

TYPE OF ACTIVITY	NUMBER OF ACTIVITIES
Geologic mapping stations	81
Shallow refraction lines	6
Electrical resistivity soundings	6

ENGINEERING—LABORATORY TESTS

TYPE OF TEST	NUMBER OF TESTS
Moisture/density	164
Specific gravity	5
Sieve analysis	112
Hydrometer	4
Atterberg limits	46
Consolidation	9
Unconfined compression	18
Triaxial compression	4
Direct shear	71
Compaction	8
CBR	8
Chemical analysis	12

ENGINEERING

NUMBER OF BORINGS	NOMINAL DEPTH FEET (METERS)
3	160 (49)
3	100 (30)
5	50 (15)
NUMBER OF TRENCHES	**NOMINAL DEPTH FEET (METERS)**
31	14 (4)
NUMBER OF TEST PITS	**NOMINAL DEPTH FEET (METERS)**
21	10 (3)
NUMBER OF CONE PENETROMETER TESTS	**NOMINAL DEPTH FEET (METERS)**
47	33 (10)
11	SAME AS NEAREST BORING

SCOPE OF ACTIVITIES
OPERATIONAL BASE SITE
BERYL, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE — BMO

TABLE 3-2

FUGRO NATIONAL, INC.

Permits for access were arranged through the District Office of the Bureau of Land Management (BLM). At BLM's request, all field activities were performed along existing roads or trails to minimize site disturbance. Archaeological and environmental surveys were performed at each proposed activity location. Activity locations were changed in those few instances where a potential environmental or archaeological disturbance was identified. Brief descriptions of each type of activity follow.

3.2.1 Geologic Mapping

The primary objectives of the field geologic mapping were to identify any geologic hazards or adverse conditions not identified in previous studies and to delineate and define soil and rock units. Color aerial photographs (1:25,000 scale) were used as a mapping base. The field data were subsequently transferred to 1:24,000 scale topographic maps.

3.2.2 Borings

Rotary wash techniques were used to drill borings to depths ranging from approximately 50 to 160 feet (15 to 49 m) below the existing ground surface. Both undisturbed and representative soil samples were taken at various depths for laboratory testing.

3.2.3 Trenches and Test Pits

Trenches and test pits were excavated at selected locations to determine characteristics of the shallow subsurface soils. Bulk samples were taken for laboratory testing.

3.2.4 Cone Penetrometer Tests (CPTs)

Cone penetrometer tests were performed to supplement borings, to obtain continuous soil information, and to estimate in-situ soil properties.

3.2.5 Seismic Refraction Surveys

Six shallow seismic refraction surveys were conducted to determine the depth and configuration of subsurface velocity layers.

3.2.6 Electrical Resistivity Surveys

Six resistivity surveys were performed to provide data on the electrical properties of the subsurface soils.

3.3 LABORATORY TESTING

Laboratory testing was performed on representative soil samples to determine the engineering properties of surface and subsurface soils. The testing program included soil classification, moisture/density, Atterberg limits, compaction, California Bearing Ratio (CBR), triaxial shear, unconfined compression, direct shear, and consolidation tests. In addition, chemical tests were performed on representative samples from various soil layers. Testing procedures, which are in general compliance with the American Society of Testing Materials (ASTM) standards, are discussed in Section A4.0 of Appendix A. The number of tests performed is summarized in Table 3-2.

3.4 ANALYSES, CONCLUSIONS, AND RECOMMENDATIONS

Following the field and laboratory investigations, analyses were made of all the collected data. These included studies of land

status in the study area, cultural conditions, depths to shallow rock and water, locations of faults and lineaments, and types and properties of surface and subsurface soils. Following the analyses, conclusions and recommendations were developed regarding site suitability; potential geotechnical hazards such as flooding and ponding, faults and seismicity, subsidence, sand dunes, and rockfall; stability of natural and cut slopes; location of potential aggregate sources; types of foundations for the various structures and their allowable bearing pressures; and construction considerations.

4.0 GEOGRAPHIC AND CULTURAL CONDITIONS

4.1 LOCATION

The proposed Beryl OB site is located in Iron County, southwestern Utah, in the southwestern portion of the Escalante Desert (Figure 2-1). The Escalante Desert is an irregularly shaped valley which extends approximately 90 miles (144 km) in a northeasterly direction from Modena to about 30 miles (50 km) north of Milford. The desert is approximately 40 miles (64 km) across at its widest point. In the site area, the Escalante Desert is bounded on the northwest by a series of east-northeast trending mountains constituting the southern extensions of the Needle Range (locally called North Peaks) and the Wah Wah Range. Maximum elevations locally reach 8156 feet (2486 m) (Hamblin Peak); the lowest elevation of the valley floor is about 5100 feet (1555 m) near Lund.

4.2 CULTURAL FEATURES

The largest communities near the site are Cedar City (approximately 30 miles [50 km] southeast of the site) with a population of 10,881 (Iron County Clerk, 1981) and Enterprise, approximately 30 miles (50 km) south of the site with an estimated population of 1000 (Day, 1980). Other small communities in the area are Newcastle, Lund, Beryl Junction, Beryl, and Modena (Figure 2-1). These communities proper have populations that are generally less than 50; rural populations around some communities can be as large as 450.

The primary highways in the site vicinity are state highways 19, 56, and 18. Highway 19 trends northwest from Cedar City toward Lund, the northeastern corner of the site area, a distance of 31 miles (50 km). Highway 56 runs approximately east-west, connecting Cedar City with Beryl Junction and Modena in Utah, and Panaca in Nevada. Highway 18 connects Beryl Junction with Enterprise to the south and with Beryl to the north (Figure 2-1).

The Union Pacific Railroad traverses the western margin of the Escalante Desert and marks the approximate southeastern boundary of the site area. Several small communities and crossings occur along the railroad tracks including Lund, Zane, Beryl, Yale Crossing, Heist, and Modena. The proposed route of the Intermountain Power Project 500-kilovolt (direct current) Line #1 lies along the northwestern portion of the OBTS and bisects the proposed Base Housing area.

4.3 LAND STATUS

The study area, like the rest of Escalante Desert, consists of state and private property and public lands (Drawing 4-1). The chief land use in the area is ranching; only about 340 acres (137.4 hectares) are being farmed. Less than half of the area consists of public lands administered by the BLM from their Cedar City District Office.

Two Known Geothermal Resource Areas (KGRA), one east of Lund and the other near Newcastle, are located within the western Escalante Desert outside the study are a proper. These KGRAs total approximately 6400 acres (2585.6 hectares). The majority of the

valley and portions of the study area have potentially usable geothermal resources (Utah Geologic and Mineral Survey, 1980).

5.0 GEOTECHNICAL CONDITIONS

5.1 REGIONAL GEOLOGIC SETTING

The proposed OB site lies within the eastern portion of the Great Basin subdivision of the Basin and Range Physiographic Province. The Great Basin, which includes Nevada, western Utah, and small portions of Oregon, Idaho, California, and Arizona, is characterized by north-south trending mountains separated by broad desert valleys which generally contain thick accumulations of basin-fill deposits.

Relief between valleys and adjoining mountains is generally less than 5000 feet (1500 m). Typically, the valleys are closed basins with internal drainage. During Pleistocene time, many of these basins were occupied by extensive lakes produced by climatic adjustments that occured during glacial periods. The eastern portion of the site area lies within the southern part of the Bonneville Basin, the section of the Great Basin that once contained Lake Bonneville, the largest of the Pleistocene lakes. Locally, the proposed OB site includes the alluvial slopes and valley bottom along the northwestern side of Escalante Desert, Utah.

5.2 SITE GEOLOGIC UNITS

The proposed OB site is underlain primarily by sedimentary deposits of Pleistocene (Bonneville and pre Bonneville) and Holocene ages. Pleistocene deposits locally in clude alluvial fan and lake sediments. Holocene units include unconsolidated alluvial fan, stream channel, and eolian deposits.

The mountain ranges bounding the site area are composed of Tertiary and possibly Quaternary volcanic rocks with isolated outcrops of pre-Cenozoic rock. Drawing 5-1 (Geologic Map) shows the surficial distribution of the bedrock and basin-fill units. The following sections discuss the bedrock and basin-fill deposits in order from oldest to youngest.

5.2.1 Bedrock

5.2.1.1 Pre-Cenozoic Rock (Pzc)

Outcrops of pre-Cenozoic bedrock occur as isolated hills in the Webster's Knolls area. These outcrops are shown on existing published maps as Quaternary basalt (Hintze, 1963). Our studies have demonstrated that the rock consists of fine-crystaline quartzite of probable Paleozoic age. Recrystalization of the quartzite has been sufficiently intense to obscure bedding structures. The rock is cut by subvertical joints spaced from 1 to 2 feet (0.3 to 0.6 m) apart, striking from N 60° W to N 20° W.

5.2.1.2 Tertiary and Possible Quaternary Volcanic Rocks (Tv)

The mountains bounding the site consist exclusively of volcanic rock. The predominant rock types are ash flow sheets of intermediate composition and acidic to basic volcanic flows. The ash flows range from a reddish-brown, fine-grained rock with marked flow banding, to a light-colored, coarse granular rock with occasional massive bedding. The volcanic flows occur as reddish, fine-grained porphyritic rocks with flow banding grading to

brecciated textures. Bedrock slopes adjacent to the valley margin are generally rubble-covered with few outcrops.

The volcanic sequence of the area has been interpreted as ash-flow sheets deposited in an east-trending trough or graben during late Oligocene to Lower Miocene time (35 to 19 million years ago). These ash-flows were surmounted by contemporary Tertiary lava flows and volcanic breccias (Conrad, 1969).

Outcrops of a well-cemented fanglomerate occur near bedrock exposures at the base of two canyons (Negro Liza Wash and Fourmile Wash). The fanglomerate consists of moderately well-bedded gravelly sandstone and conglomerate with angular to subangular clasts of variegated volcanic rock. Bedding in the fanglomerate strikes N 50° W and dips 17 degrees to the southwest. The regional geologic setting of these rocks favors the interpretation that this unit is interbedded within the Tertiary volcanic sequence.

Isolated outcrops of basalt occur in Black Reef and in areas north of Webster's Knoll. The basalt ranges from massive to vesicular and is dark grey to black in color; blocky jointing is common. According to Hintze (1963), the age of these rocks is Quaternary, but Luedke and others (1979) give them a late Tertiary age.

5.2.2 Older-Age Alluvial Fan Deposits (A5o)

Older-age alluvial fan deposits comprise about three percent of the area mapped. These deposits occur in the northwestern portions of the site, adjacent to the mountain front. Older-age

fans are easily differentiated from intermediate-age alluvial fans both in aerial photographs and in the field by their higher elevations and greater degree of dissection. The sediments that compose these fans consist predominantly of massive to poorly bedded, light-brown gravel with small amounts (10 percent) of fines and a cobble content ranging from five to 15 percent. The clasts (gravels, cobbles, and boulders) consist of subangular, hard volcanic rock fragments mostly of basaltic composition. In some areas, the gravel is overlain by 2 feet (0.6 m) of brown, massive silty sand that contains less than 10 percent gravel. The consistency of this unit is dense to very dense. A conspicuous pedogenic caliche horizon (Stage III to Stage IV), averaging 3 feet (0.9 m) in thickness, occurs 1 to 2 feet (0.3 to 0.6 m) below the surface. The caliche layer is very dense and well-cemented. The surface of the older-age fans has scattered boulders (mostly of basaltic composition) and fragments of caliche from the partially exhumed fan surface.

5.2.3 Intermediate-Age Alluvial Fan Deposits (A5i)

A5i deposits comprise approximately 80 percent of the site area. The soil within this unit consists predominantly of light-brown, poorly to moderately well-bedded, gravelly sand with 13 to 20 percent fines (silt and clay) and with pebbles and cobbles seldom exceeding 20 percent.

Lenses of gravel, cobble, and/or silt are occasionally found within the unit. The clasts in the gravel are subangular to subrounded volcanic rock fragments with minor amounts of quartzite and limestone. These deposits are generally overlain by a

few inches to 1 1/2 feet (0.4 m) of reddish-brown silty to clayey sand. A well-developed layer of pedogenic caliche (Stages III and occasionally IV) about 3 feet (0.9 m) thick occurs between 1 and 2 feet (0.3 and 0.6 m) below the surface. This cemented layer is best developed near the mountain fronts and in the western portions of the site. Where found in conjunction with a highly gravelly or cobbly layer, it constitutes a local refusal layer for excavation.

5.2.4 Mixed Pleistocene Lake Deposits With Young Alluvial Fan (A4o/A5y) and Eolian Deposits (A4o/A3s)

Approximately 10 percent of the area is covered by Pleistocene lake deposits and either young alluvial fans (A5y) or eolian deposits (A3s). Subdued shoreline features at 5200 feet (1585 m) elevation are present indicating that old lacustrine deposits underlie most of the areas adjacent to the railroad.

The deposits consist mainly of moderately well-bedded, light brown sandy silt and clayey sand. Interbedded gravelly sand and gravel with less than five percent fines occur in lenses up to 4 feet (1.2 m) in thickness. The lenses may be of fluvial or deltaic origin. The consistency of the sediments is medium dense. A pedogenic caliche horizon (Stage I or Stage II) commonly occurs between 1 and 5 feet (0.3 and 1.5 m) below the surface.

The lake deposits have been reworked and partially overlain by young alluvial fans (A5y) and eolian deposits (A3s) to an average depth of about 5 feet (1.5 m).

5.2.5 Young Alluvial Fan Deposits (A5y)

Young alluvial fan deposits comprise approximately 10 percent of the study area. This unit consists of poorly to moderately well-bedded, reddish-brown sands and fines (clay and silt) with a gravel content of up to 10 percent near the mountain front. The percentage of fines increases toward the distal portions of the fans. Interbedded lenses of silt and gravel are common. Gravel clasts consist of subangular volcanic rock fragments in the western areas, with some quartzite fragments in the central areas and a trace of limestone clasts toward the east near Lund. In areas adjacent to the railroad, the young fans consist mostly of clayey and sandy silt partially derived from reworked Pleistocene lake deposits (A4o). The consistency of the A5y fans is loose to medium dense, with a Stage I to II caliche horizon, about 1 foot (0.3 m) thick occurring between 1.5 and 2 feet (0.4 and 0.6 m) below the surface.

5.2.6 Young Fluvial Deposits (A1)

Young fluvial deposits comprise less than five percent of the mapped site area. These deposits consist of recent stream-channel and flood-plain deposits such as those in Negro Liza Wash, Mountain Spring Wash, and Fourmile Wash. The near surface deposits are dominantly very loose, uncemented gravel, gravelly sand, and silty sand. The gravel generally consists of subangular to subrounded pebbles and cobbles of volcanic rocks. The clasts are usually unweathered; caliche coatings are partial or absent. Generally, 3 to 5 feet (0.9 to 1.5 m) below the surface the A1 deposits become slightly indurated and are edium

dense. The A1 deposits are commonly lensed and vary in composition and consistency both laterally and vertically.

5.2.7 Eolian Deposits (A3d, A3s, A3s/A4o)

Eolian deposits cover between five and 10 percent of the area mapped. These deposits consist of sand dunes (A3d), sheet sands (A3s), and sheet sands developed on lake deposits (A3s/A4o) in varying proportions. Eolian deposits occur primarily in two areas: 1) immediately north of Beryl, and 2) north of the railroad tracks 4 1/2 miles (7.5 km) west of Beryl.

The dunes (A3d) consist of fine to medium sand with less than 25 percent fines and with a high calcium-carbonate content in the form of subrounded to subangular sand-size particles. The dunes generally do not show a preferred orientation, except in an area north of Beryl where they are aligned in a northwesterly direction, perpendicular to the prevailing local winds. Average heights are approximately 4 feet (1.2 m) with maximum heights of 15 feet (4.5 m). Deflated areas between the dunes consist of less well-sorted sediments containing higher percentages of fines and some fine gravels.

The sheet sands (A3s) consist of a thin veneer 8 to 11 inches (20 to 30 cm) thick of reworked lake deposits (very loose to loose silty sand). They generally represent areas devoid of vegetation. Immediately underlying the sheet sands is a silty sand layer with a high content of caliche fragments and Stage I caliche development.

5.3 SUBSURFACE CONDITIONS

5.3.1 Thickness of the Basin-Fill Deposits

The following discussion presents the estimated thicknesses of the basin-fill deposits interpreted from literature data, boring logs, and the results of geologic field mapping.

- o Older-Age Alluvial Fan Deposits (A5o) - The surficial extent of these fans is small and limited to areas adjacent to the mountain front. No available evidence has shown that they underlie intermediate-age alluvial fans. Depth of incisions present in these older fans, which at places exceed 80 feet (24.4 m), would represent a minimum value for the thickness of this unit.

- o Intermediate-Age Alluvial Fan Deposits (A5i) - These deposits are probably thickest toward the valley margin and thin toward the central portion of the valley. A previous boring through this unit (Utah State Engineers Office, drillers' log) encountered bedrock at approximately 180 feet (55 m) deep, 2 miles (3 km) away from the mountain front. Assuming that only intermediate-age fan deposits were penetrated, a maximum thickness of about 180 feet (55 m) is estimated for this unit.

- o Pleistocene Lake Sediments (A4o) - Similar lake deposits in other parts of the Lake Bonneville basin are known to be greater than 230 feet (70 m) thick (Morrison, 1966). The A4o deposits at the site, however, represent the thin shoreline edge of the lacustrine deposits in Escalante Desert and probably do not exceed several tens of feet in thickness.

- o Young Alluvial Fan Deposits (A5y) - This unit appears to consist of a relatively thin veneer a few feet thick overlying the older basin-fill units. Field data suggest this unit does not exceed 20 feet (6 m) thick near the valley margins and is probably less than 10 feet (3 m) thick away from the mountain front.

- o Eolian Deposits (A3d and A3s) - Sand dunes (A3d) range from about 1 foot (0.3 m) to a maximum of about 15 feet (4.6 m) in height, with an average height of about 4 feet (1.3 m). Sheet sands (A3s) within the site area range from a few inches to about 1 foot (0.3 m) thick.

5.3.2 Subsurface Soils

Near the western margin of the site area, gravel and sand of younger-, intermediate-, and/or older-age alluvial fan deposits

are encountered to depths of at least 80 feet (24 m). These deposits probably thin toward the southeastern edge of the area mapped. Approximately 10 percent of the study area along the railroad (Drawing 5-1) is covered by a mixed lacustrine-alluvial unit. These deposits consist of sands, silts, and/or clays and probably do not exceed several tens of feet in thickness.

The physical properties of these subsoils are summarized in Table 5-1. Descriptions of these soils are as follows:

- Gravels (GP, GW, GM) - The gravels consist of poorly to well-graded sandy gravel and silty gravel. They are fine to coarse with variable amounts of sand (27 to 49 percent) and silt (five to 19 percent). The shape of the particles varies from angular to subrounded. The density of the gravels ranges from medium dense to very dense. The moisture contents are between 3.3 and 14.9 percent. The degree of caliche cementation in the gravels is variable, ranging from none to Stage IV. Cobbles and boulders are occasionally present in these deposits in amounts ranging from zero to 25 percent.
- Sands (SP, SW, SM, SC) - The sands consist of poorly to well-graded gravelly sand, silty sand, and clayey sand. They range from fine to coarse with variable amounts of gravel (zero to 45 percent) and fines (two to 49 percent). The shape of the sand particles varies from angular to subrounded. The density of the sands ranges from loose to very dense. The moisture contents of the sands are between 4.5 and 22.4 percent. The fines in the sands are nonplastic to slightly plastic. The degree of caliche cementation is variable, ranging from none to Stage IV. Cobbles up to 12 inches (30 cm) in diameter are infrequently present in amounts up to approximately 10 percent.
- Silts and Clays (ML, MH, CL, CH) - These materials include sandy silt, silt, silty clay, and clay and contain sand in amounts ranging from eight to 49 percent. The consistency varies from firm to hard. The moisture contents are between 9.7 and 28.6 percent. The plasticity of these soils varies from nonplastic to highly plastic. The silts and clays are variably caliche-cemented, ranging from none to Stage IV.

5.3.3 Depth to Rock

Boring and seismic refraction data, field mapping, and the geologic literature suggest that bedrock will be encountered at

SOIL DESCRIPTION		GRAVEL		
		Sandy GRAVEL, Silty GRAVEL		Gravelly
USCS SYMBOLS		GP, GW, GM		
DRY DENSITY	pcf (kg/m^3)	94.6 - 128.2 (1516 - 2054)	[36]	79.4 - 1
MOISTURE CONTENT	%	3.3 - 14.9	[36]	4.5 22
CEMENTATION		NONE TO STAGE IV		
COBBLES 3 - 12 INCHES (8 - 30 cm)	%	0 - 25		0 10
GRAVEL	%	41 - 64	[10]	0 - 45
SAND	%	27 - 49	[10]	37 - 90
SILT AND CLAY	%	5 - 19	[10]	2 - 49
LIQUID LIMIT		NDA		28 - 43
PLASTICITY INDEX		NP	[1]	NP - 14
COMPRESSIONAL WAVE VELOCITY	fps (mps)	1230 - 2800 (375 - 853)		1230 -

NOTES: [ ] - NUMBER OF TESTS PERFORMED
NDA - NO DATA AVAILABLE (INSUFFICIENT DATA)
NP - NONPLASTIC

SAND		SILT AND CLAY	
Silty SAND, Clayey SAND		Sandy SILT, SILT, Silty CLAY, CLAY	
SW, SM, SC		ML, MH, CL, CH	
2 - 2105)	[109]	71.1 111.1 (1139 - 1780)	[18]
	[109]	9.7 28.6	[18]
TO STAGE IV		NONE TO STAGE IV	
		0	
	[60]	0 -2	[11]
	[60]	8 49	[11]
	[60]	51 92	[11]
	[4]	29 67	[9]
	[19]	NP 35	[13]
- 1006)		2450 (747)	

PHYSICAL PROPERTIES OF SUBSOILS
OPERATIONAL BASE SITE
BERYL, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

TABLE 5-1

FUGRO NATIONAL, INC.

2

shallow depths adjacent to the mountain fronts and near isolated bedrock outcrops such as those at Webster's Knolls and Black Reef (see Drawing 5-1). The western half of the study area probably does not have rock within 160 feet (49 m) of the surface, and no isolated outcrops occur to suggest the presence of shallow rock. In the eastern half of the area, numerous isolated rock outcrops occur, as in the Webster's Knolls area and Black Reef. Borings (Utah State Engineers Office, driller's log) penetrated rock at 180 feet (60 m) in areas 2 to 3 miles (3 to 5 km) away from the mountain front. Due to the type of rock units present in the area (Tertiary volcanic flows and ash-flows), rock is expected to occur within 150 feet (45.7 m) of the surface in the eastern half of the site area, up to 3 or 4 miles (5 or 6 km) away from the mountain front.

5.3.4 Depth to Water

Data from published literature, Fugro National, Inc. borings and observation wells, and water-level measurements in existing wells were used to construct the Depth to Water Map (Drawing 5-2). In general, depth to water increases to the northwest toward the mountain front. Near the mountain front, the depth to water is greater than 160 feet (49 m). In areas adjacent to the railroad, the depth to ground water ranges between 30 and 50 feet (9 and 15 m).

The depth-to-water contours shown on the map are based on interpretations from widely spaced data points (wells). Because of the small number and wide spacing of data points, the depth to

water will likely vary at some locations from depths indicated on the map. The data discussed here and presented in Drawing 5-2 are intended solely for preliminary identification of areas of potential construction problems due to shallow water. A more-detailed report assessing the water resources of the study area is underway and is expected to be published in May 1981.

5.4 TERRAIN AND DRAINAGE

Terrain conditions in the study area are characterized by level to gently sloping surfaces with generally broad, shallow incisions. Incision depths range from less than 1 foot (0.3 m) to more than 50 feet (15 m) in a few major washes. Surface slopes range from over 10 percent in areas adjacent to the mountain fronts to nearly flat toward the valley floor.

Areas near the mountain fronts underlain by A5i deposits have broad incisions averaging 6 feet (1.8 m) in depth and ranging from 3 to 10 feet (0.9 to 3.0 m). Slopes in these areas range from three to five percent. Toward the valley floor, incisions are shallower in both the A5i and the A5y units, averaging 3 feet (0.9 m) and ranging from 2 to 10 feet (0.6 to 3.0 m). The divides between incisions are relatively flat and smooth.

Southeast of Webster's Knolls, the A5i fan surface is nearly flat with surface slopes averaging two percent.

Terrain on the A5o alluvial fans is characterized by greater dissection and steeper surface slopes than in the A5i fans.

Drainage depths may exceed 50 feet (15 m) and average 30 feet (9 m); surface slopes locally exceed 10 percent.

Surfaces underlain by older lacustrine (A4o) or mixed lacustrine and younger deposits (A4o/A5y) are flat, with local hummocky topography (averaging 4 feet [1.2 m] relief) in areas of eolian deposits (A3d).

Four large drainages with general north-south trends exit the mountain front and traverse the site area. These drainages are, from west to east, Mary's Hollow, Negro Liza Wash, Mountain Spring, and Fourmile Wash. Their incision depths range from 25 to 50 feet (8.0 to 15 m) adjacent to the mountain fronts but decrease to less than 10 feet (3.0 m) within a distance of 2 to 3 miles (3 to 5 km) into the valley.

The catchment area of this section of the Escalante Desert is relatively small. Most surface runoff water that exits the mountains north of the site percolates into the alluvial fans. However, drainage from the mountains to the west is confined to a system of channels which crosses the railroad between a point south of Heist and Yale Crossing and runs eastwards for 2 miles (3 km) before infiltrating into the basin fill. No surface water exits the site area.

5.5 GEOLOGIC HAZARDS

Geologic hazards discussed in the following sections include flooding, faults and seismicity, subsidence, dune and sheet sands, and rockfall (Drawing 5-4).

5.5.1 Flooding

Evaluation of the flooding potential for the proposed site area consisted of aerial photograph analysis and limited field observations. No hydrographic studies or calculations were performed.

The aerial photograph analysis consisted of assessing the drainage patterns and determining which stream channels appear to be recently active (i.e., would contain water during a rainstorm). The field observations were aimed at determining the most active channels based on surficial characteristics. Areas of potential flooding are shown in the Geologic Hazards Map (Drawing 5-4).

Areas of potential flooding hazards occur within young alluvial fans and in areas of mixed young fans and old lake deposits. Field evidence indicates that the flooding is probably of low energy; i.e., stream gradients are low, and stream-bed loads are fine-grained. The area of potential flood hazards at the mouth of Mountain Spring Wash corresponds to the downfan emergence of the previously entrenched channel; here, the flow becomes unconfined and fine detritus is deposited. Another area of potential flood hazards originates at the confluence of two large drainage systems and crosses the Operational Base. The remainder of the potential flood areas occur below the Lake Bonneville shoreline (approximately at 5200 feet [1585 m] elevation) and are probably a consequence of the shallow surface gradient and more impervious nature of the lacustrian soils in these areas.

5.5.2 Faults and Seismicity

Several faults (Drawing 5-1), generally striking northeasterly, have been mapped from aerial photographs and observed in the field. Several of these faults offset late Quaternary basin-fill deposits (less than 700,000 years old) and therefore are regarded as potentially active. In some cases, these faults offset basin-fill deposits of Lake Bonneville age (12,000 years old) or younger; these faults should be regarded as active.

One of the more prominent northeasterly striking faults in the Beryl region is located west of Lund. The surface expression of this fault consists of a pronounced southeasterly facing scarp that averages approximately 27 feet (8 m) in height; in young alluvial deposits, the scarp is only about 1 foot (0.3 m) high. This fault is fairly continuous from southeast of Zane to northwest of Lund Flats, a distance of about 12 miles (19 km) (Drawing 5-1). Approximately 3 miles (5 km) southeast of Zane, a smaller fault, with a northwest facing scarp, parallels the main fault at Lund, forming a trough or graben with extensive eolian deposits for a distance of about 3 miles (5 km).

Several east-west and northeasterly trending linear features were mapped on the aerial photographs in the proposed site area and are shown on the geologic map (Drawing 5-1). These features are expressed as linear vegetation concentrations and tonal changes. Field observations suggest that at least some of the features are probably not faults.

The Beryl siting area has a low level of seismicity with only a few widely scattered small-magnitude events (4.0 magnitude or less) (Drawing 5-5). An area of relatively high seismicity, the Intermountain Seismic Belt (ISB) is about 30 miles (48 km) southeast of the site area. The ISB is a northeast trending belt of seismic activity that extends from Montana through Utah along the Hurricane and Wasatch faults and into southern Nevada and Arizona. Numerous faults associated with the Intermountain Seismic Belt show evidence of Late Quaternary and Holocene movement (Swan and others, 1980; and Hamblin and Best, 1970). In the Cedar City region, the system of young faults is about 50 miles (80 km) wide. The major faults in this system are the Hurricane fault, located about 30 miles (48 km) southeast of the site area, and the Wasatch fault, located about 105 miles (169 km) (Anderson and Miller, 1979) north of the site area.

5.5.3 Subsidence

According to Mower and Cordova (1973), fracturing and subsidence of the land surface in the Milford area have occurred as a result of ground-water withdrawal. Mining of ground water in the Milford area (between 1950 and 1972) led to local ground-water level declines of as much as 30 feet (10 m). Comparable declines, in excess of 30 feet (9 m), have occurred in the Beryl Junction area between 1950 and 1980. The area of maximum ground-water level decline appears to be at least 11 miles (18 km) southeast of the proposed Beryl OB site. Ground fracturing, assumed to be associated with subsidence due to ground-water

withdrawal, has been observed in an area 5 miles (8 km) northeast of Newcastle (20 miles [32 km] southeast of the proposed Beryl site). No earth fractures or other signs of subsidence were noted in the vicinity of the site.

5.5.4 Sand Dunes and Sheet Sands

Several sand dune fields occur near the site area (Drawing 5-4). The average height of the dunes is about 3 feet (1 m) with a maximum height of about 15 feet (5 m).

Most of the dunes and sheet sands are relatively stable as shown by comparison of 1953 versus 1978 aerial photographs. However, longitudinal dunes east of Zane have migrated northeasterly at a rate of about 50 to 60 feet (15 to 18 m) per year, and areas near Beryl that were under cultivation in 1953 can be seen in the 1978 aerial photos to be covered by eolian deposits.

5.5.5 Rockfall

No evidence of major rockfall hazard or landslide-related phenomena were observed within the site area. The mountain front does not have steep relief, and no large boulders, rock fragments, or rockfall talus accumulations were observed along it.

6.0 DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

6.1 SITE SUITABILITY

Site conditions including depths to rock and water, terrain, flooding, faults, and rockfall are summarized in Table 6-1. These interpretations are based on boring and seismic refraction data, field mapping, the regional geologic setting and geologic literature.

6.1.1 Depth to Rock

No rock is expected to occur within 150 feet (46 m) of the surface in the proposed MOB, DAA, and all but the grade test track of the OBTS. The northern and northwestern portions of the proposed BH have rock exposed at the surface; however, a 50-foot (15-m) deep boring located in the southeastern portion of the BH area did not encounter rock. Rock is found at the surface in approximately 75 percent of the OBTS grade test track area.

6.1.2 Depth to Water

All of the proposed DAA, the BH area, the OBTS grade test track, and the northwesterly portion of the proposed MOB are located in areas where the depth to water is estimated to be greater than 150 feet (46 m) (Drawing 5-2). The southern and eastern portions of the proposed MOB are interpreted to have depths to ground water of between 50 and 150 feet (15 and 46 m). The southern half of the proposed OBTS has estimated depths to water ranging from 100 to 150 feet (30 to 46 m) below the surface. In the northern half of the main OBTS area, water is probably at depths greater than 150 feet (46 m).

	PROPOSED MAIN OPERATIONAL BASE	DES
FLOODING (Drawing 5-4)	potential flooding in the southwestern portion	
FAULTS (Drawing 5-) approximate strike; geologic units cut by faults	none	
ROCKFALL HAZARD	none	
TERRAIN (Drawing 5-3)		
percent of activity center exceeding 5 or more drainages 10 feet deep per 1000 feet	none	
percent of activity center underlain by ≥ 5% and < 10% slope	none	
percent of activity center underlain by ≥ 10% slope	none	
average incision depth	4 feet (1m)	
maximum incision depth	8 feet (2m)	
average surface slope	2%	
maximum surface slope	2%	
DEPTH TO ROCK	greater than 150 feet (46m)	gre
DEPTH TO WATER (Drawing 5-2)	less than 100 feet (31m) to greater than 150 feet (46m)	gre
PERCENTAGE OF SURFICIAL GEOLOGIC UNIT UNDERLYING PROPOSED ACTIVITY CENTER (Drawing 5-1)	A5is 53% A5yf 24% A5ys/A5is 11% A5ys 7% A5ys/A4of 3% A1s 2%	A5i A5y A1s

PROPOSED DESIGNATED ASSEMBLY AREA	PROPOSED OPERATIONAL BASE TEST AND TRAINING SITE	PROPOSED BASE HOUSING
potential flooding in the central portion	none	none
none	(Grade Test Track) NE Tv	NS Tv
none	none	none
none	none	3%
none	none Grade Test Track 1%	60%
none	1% Grade Test Track 1%	8%
5 feet (2m)	5 feet (2m)	4 feet (1m)
10 feet (3m)	10 feet (3m)	40 feet (12m)
2%	2%	5%
2%	> 10% (Grade Test Track)	> 10%
greater than 150 feet (46m)	greater than 150 feet (46m) except less than 50 feet (15m) in the grade test tract	less than 50 feet (15m) in northern portions; greater than 50 feet (15m) in southern portions
greater than 150 feet (46m)	less than 150 feet (46m) to greater than 150 feet (46m)	greater than 150 feet (46m)
A5is 64% A5ys 32% A1s 4%	A5is 99% A1s 1% Grade Test Track: Tv 75% A5is 25%	A5ig/A5is 76% A5og 11% A5is 9% Tv 4%

SUMMARY OF GEOTECHNICAL CONDITIONS
OPERATIONAL BASE SITE
BERYL, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

TABLE 6-1

FUGRO NATIONAL, INC.

1 2

6.1.3 Terrain

Terrain conditions in the study area (Drawing 5-3) for each proposed activity center are summarized in Table 6-1.

Areas of older alluvial fans (A5o) (Drawing 5-1) have been delineated as adverse terrain based on the incision-depth and drainage-spacing criteria.

Areas with surface gradients exceeding 10 percent are restricted to a few areas adjacent to the western mountain front and sections of the channel walls of Negro Liza, Mountain Spring, and Fourmile washes.

Areas with surface gradients that exceed five percent have been outlined, and those with local surface gradients of less than five percent are indicated with arrows pointing in the downslope direction (Drawing 5-2).

No adverse terrain occurs in the proposed MOB and DAA area. A small area (three percent) of the proposed BH area has adverse terrain, and the surface slope in portions of this activity center exceeds 10 percent. A minor section in the northwestern corner of the OBTS has a greater than 10 percent slope corresponding to the channel walls of Mountain Spring Wash.

6.1.4 Geologic Hazards

Discussions and conclusions pertaining to flooding, faults and seismic conditions, subsidence, sand dunes, sheet sands, and rockfall are presented in the following paragraphs.

6.1.4.1 Flooding

Major flooding within the site area would be confined to the incised flood plains in the younger-age alluvial fans and the major incisions in the intermediate-age alluvial fans. Flooding on the A5y fans would occur as either stream or sheet floods. Stream floods would occur when water and detrital material emerge from the mountain canyons but do not overflow existing channels. The water would remain confined to definite channels in the fan surface.

Sheet floods are likely to occur when exceedingly large amounts of water and detritus emerge from a mountain canyon and overflow existing channels or spill out of the incision mouth, spreading out over broad areas of the fan surface or onto low-lying areas containing older lacustrine deposits.

Stream- and sheet-flooding areas are present in the western portion of the proposed MOB and in a small area in the central portion of the proposed DAA. A potential method to protect the roads and facilities from flooding would be diversion dikes. An alternative method would be to elevate the roads and to use elevated building pads.

6.1.4.2 Faults and Seismicity

Several of the faults in the study area appear to have displaced basin-fill deposits as young as 12,000 years old. For this level of investigation, these faults should be regarded as active. Other faults noted in the study area displace late Quaternary deposits; these should be considered potentially

active. None of the fault traces or their projections cross any of the proposed activity centers.

If the northeasterly striking fault northwest of Lund is continuous with a similarly trending fault which was previously noted to the north between Lyman Well and the Beaver/ Iron County line (Fugro, 1981, FN-TR-44), and if these traces represent one continuous fault zone, the combined length of this fault system would be about 19 miles (31 km). A 1-foot (0.3-m) scarp has been observed in Holocene deposits along this fault. Fault-length/earthquake-magnitude and fault displacement/magnitude relationships (Slemmons, 1977) suggest that such a fault could generate about a 6.5 magnitude earthquake (this is a crude estimate based on the data available and should be subject to the verifying studies described in Section 7.0). This fault system probably represents the major earthquake hazard in the immediate site area. Ground motions from earthquakes located so near to a site cannot be accurately predicted. Published attenuation relationships (Housner, 1965; Schnabel and Seed, 1973; and Donovan, 1973) and ground motions recorded during recent earthquakes, suggest that peak accelerations on the order of 1/2 g can be expected at the site from a large earthquake on the nearby fault.

Although the Quaternary fault system discussed in Section 5.5.2, which includes the Wasatch and Hurricane faults, has no known historic fault ruptures, the high rate of earthquake activity in the region (Smith and Sbar, 1974) suggests that faults in the

system have a potential for generating earthquakes. Maximum earthquakes along the Wasatch fault zone have been estimated at about 7.5 magnitude (Swan and others, 1980). The length of the Hurricane fault zone (160 miles [255 km]) suggests that earthquakes with magnitudes on the order of 7.5 are possible on that fault.

6.1.4.3 Subsidence

Effects of subsidence due to ground-water withdrawal, specifically earth cracking, have been observed in the southern Escalante Desert near Newcastle. No such effects were observed in the proposed site area. Generally, subsidence effects and earth cracking will be most pronounced near the region of greatest long-term lowering of the water table. Water table lowering in the Beryl Junction-Newcastle area between 1950 and 1980 exceeds 30 feet (9 m); by contrast, the water level in the basin-fill aquifer near the proposed site has dropped only about 10 feet (3 m). Consequently, the potential for earth cracking at the site, under the present pattern of water withdrawal, is considered to be very low. Nonetheless, the possibility of locating yet-undiscovered cracking should be considered in future geotechnical studies.

6.1.4.4 Sand Dunes

As previously discussed in Section 5.5.4, sand dunes occur in the vicinity of the proposed site. At present, these dunes appear to be stable. If the dunes do become mobile, it is likely they would move in a northeasterly direction due to

prevailing wind directions. Several of the dunes are located south and west (i.e., downwind) of proposed activity centers.

Renewed sand-dune mobility results from disturbance of the stabilized surface. Studies in the Great Basin (Melhorn and Trexler, 1977) have documented reactivated sand-dune migrations from renewed attempts to cultivate large expanses of stable basin-fill deposits. Preserving the existing vegetation and increasing the vegetative cover are possible methods for decreasing the potential for sand-dune mobility and for stabilization of new dunes. Another possible method of protecting structures and facilities from sand-dune migration would be by the use of "deflection barriers" such as those presently being used in the area to protect portions of the Union Pacific Railroad.

6.1.4.5 Rockfall

As previously discussed in Section 5.5.5, the potential for rockfall hazards appears to be extremely low.

6.2 FOUNDATION CONSIDERATIONS

Geotechnical properties of the subsurface soils in the activity centers and foundation recommendations for the structures are discussed in this section.

6.2.1. Geotechnical Properties of Subsurface Soils

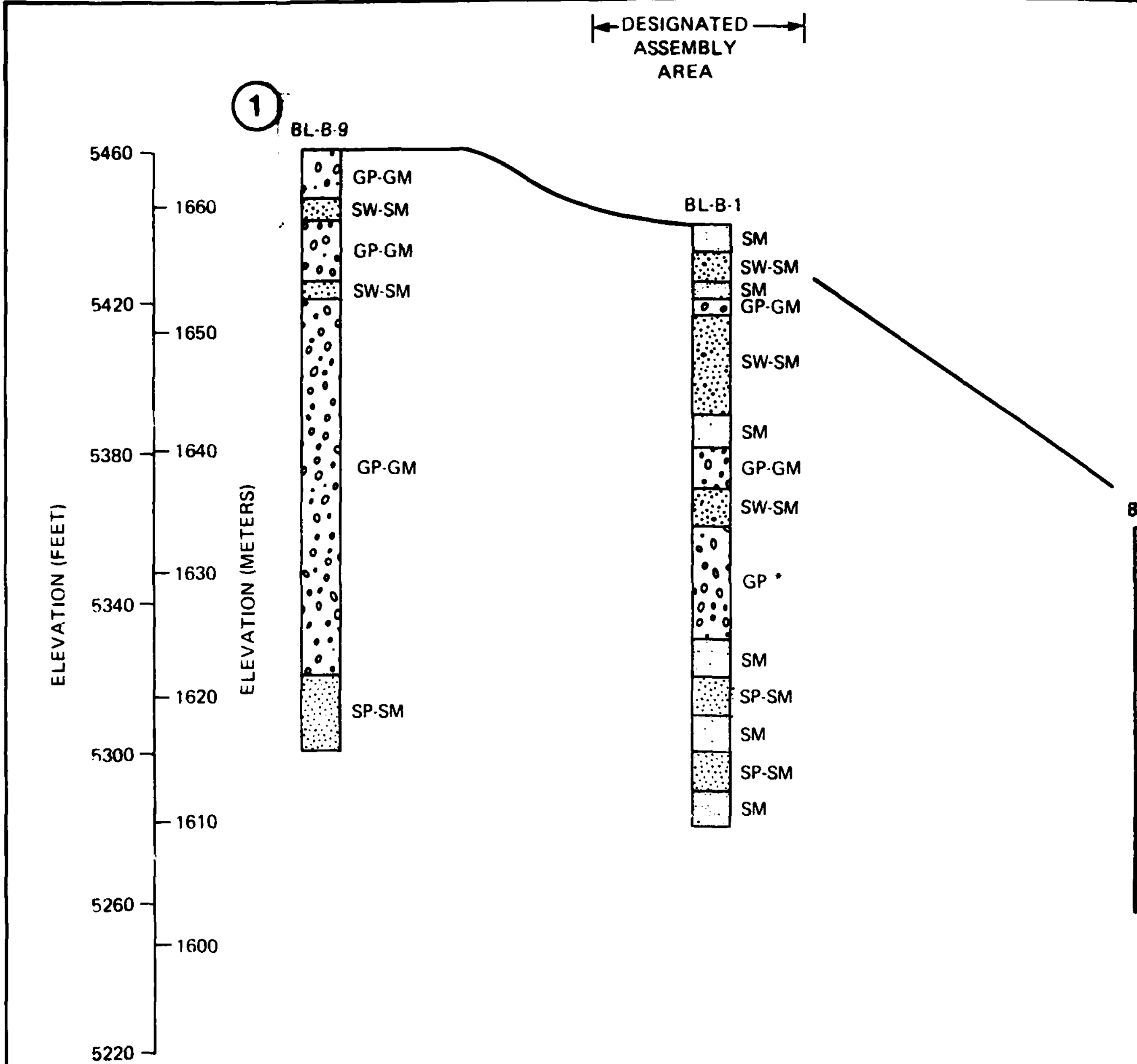
The surficial soils at the proposed Beryl OB site consist of gravels, sands, silts, and clays, with the majority being sands. Their density varies from loose to very dense to depths ranging

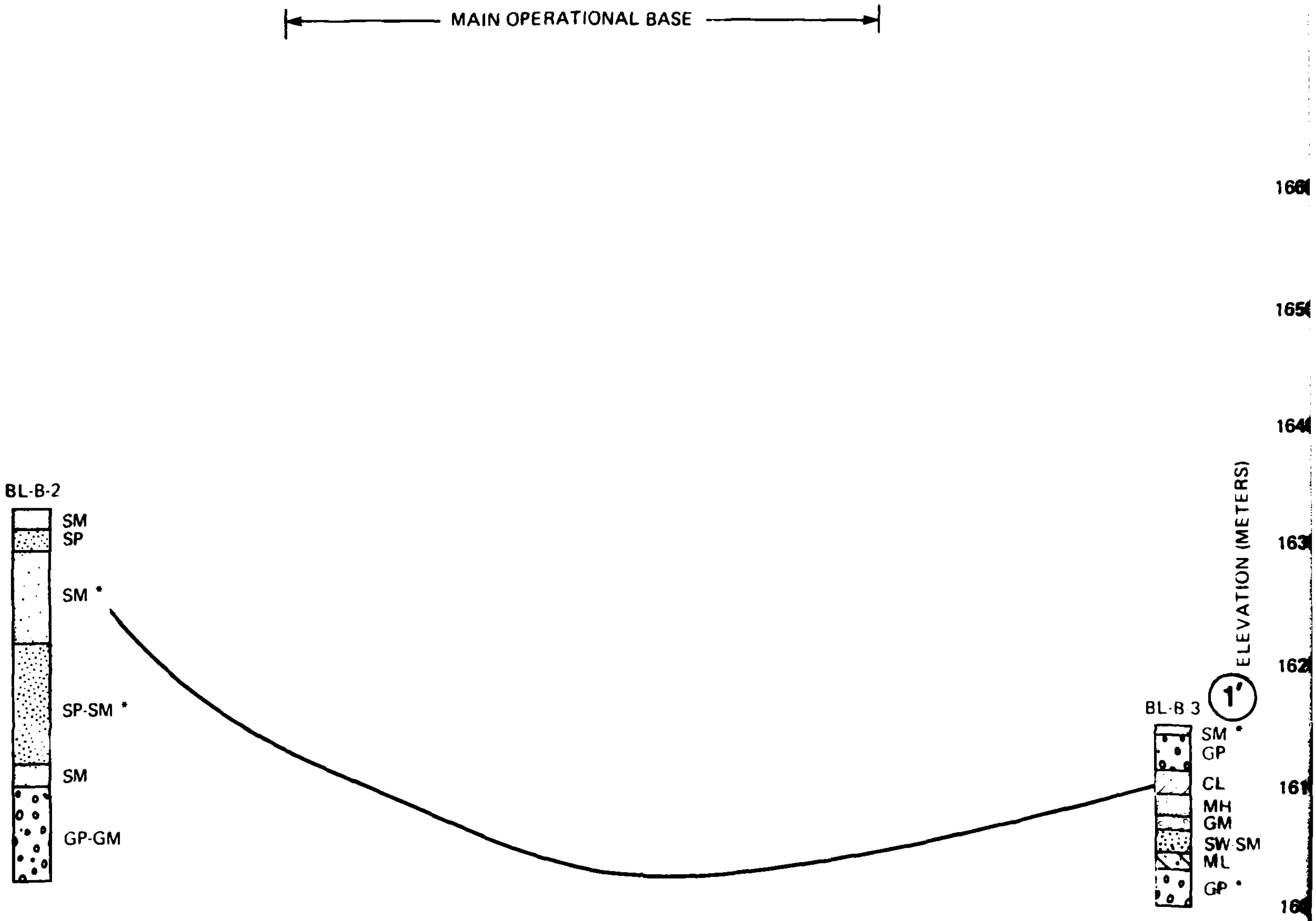
from 1 to 3 feet (0.3 to 0.9 m). The surficial soils are underlain mainly by alluvial fan gravel and sand. The southeastern portion of the study area is generally underlain by sandy silt, silt, silty clay, and clay of the lake deposits. Two soil profiles showing typical subsoil conditions are presented in Figures 6-1 and 6-2. The geotechnical properties of these subsurface soils are described as follows:

- Gravels (GP, GW, GM): The gravels consist of poorly to well-graded sandy gravel and silty gravel, ranging in particle size from fine to coarse. The density of the gravels ranges from medium dense to very dense. The gravels are predominantly matrix supported by sand. In general, the degree of caliche cementation varies from none to Stage III. However, in localized areas near the mountain front, Stage IV caliche cementation occasionally is present. The results of the CPTs indicate that the gravels have a moderate to high shear strength.

- Sands (SP, SW, SM, SC): The sands consist of poorly to well-graded gravelly sand, silty sand, and clayey sand ranging in particle size from fine to coarse. Fines in the sands are nonplastic to slightly plastic. The sands have a medium-dense to very-dense consistency. In general, the degree of caliche cementation varies from none to Stage III. However, in localized areas near the mountain front, Stage IV caliche cementation occasionally is present. The shear strength of the sands ranges from moderate to high; their compressibility is between very low and medium. The shear strength and compressibility characteristics of the sands are presented in Table 6-2.

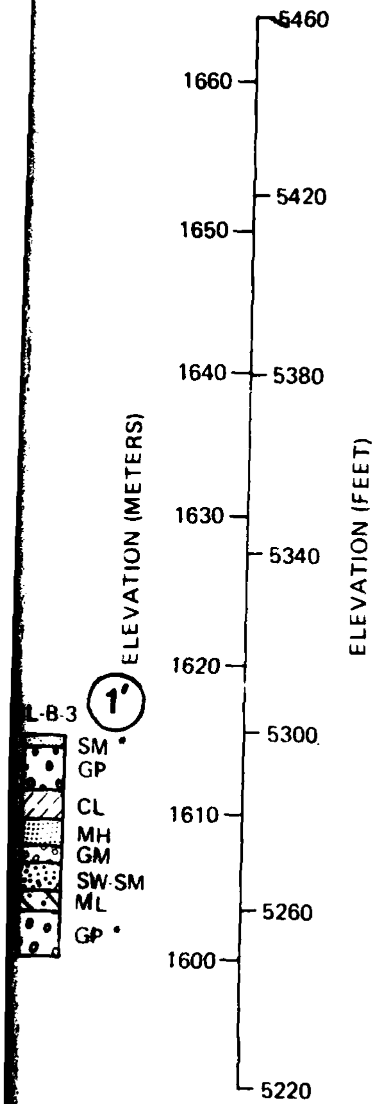
- Silts and Clays (ML, MH, CL, CH): These consist of sandy silt, silt, silty clay, and clay. They range from firm to hard in consistency and are nonplastic to highly plastic. The highly plastic materials may exhibit some shrinkage or swelling behavior when subjected to moisture content changes. The degree of cementation of the silts and clays ranges from none to Stage IV. The shear strength ranges from moderate to high. The compressibility of the silts and clays is between very low and medium. The shear strength and compressibility characteristics of the silts and clays are presented in Table 6-2.


DESIGNATED ASSEMBLY AREA
1
BL-B-9
BL-B-1
ELEVATION (FEET)
ELEVATION (METERS)
5460
5420
5380
5340
5300
5260
5220
1660
1650
1640
1630
1620
1610
1600
GP-GM
SW-SM
GP-GM
SW-SM
GP-GM
SP-SM
SM
SW-SM
SM
GP-GM
SW-SM
SM
GP-GM
SW-SM
GP *
SM
SP-SM
SM
SP-SM
SM

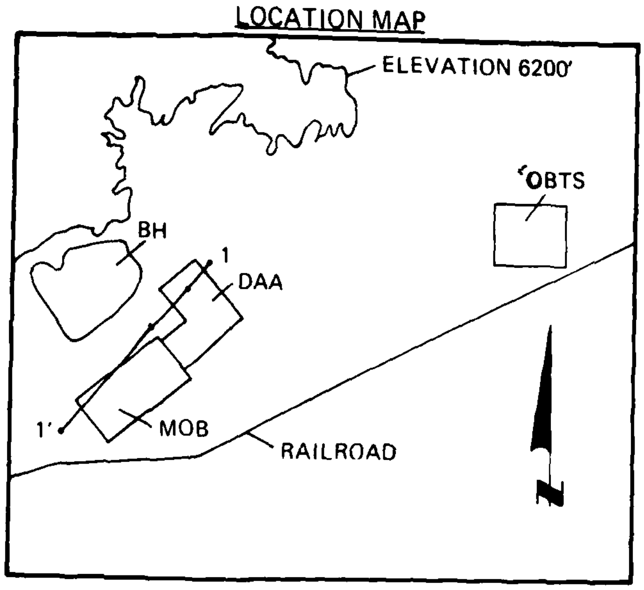


MAIN OPERATIONAL BASE
BL-B-2
SM
SP
SM *
SP-SM *
SM
GP-GM
BL-B-3
SM *
GP
CL
MH
GM
SW-SM
ML
GP *
1'
ELEVATION (METERS)
166
165
164
163
162
161

12



LOCATION MAP



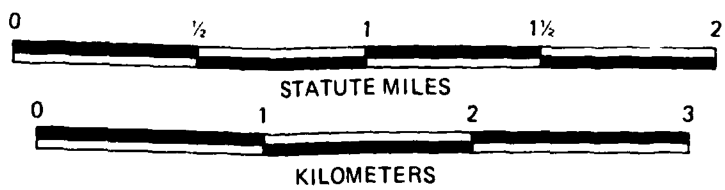
EXPLANATION

B - Boring
T - Trench
P - Test Pit

NOTES.

1. Ground surface elevations shown at activity locations are approximate.
2. Soil types shown adjacent to soil column are based on Unified Soil Classification System (USCS) and are explained in the appendix.
3. * - indicates that only the predominate soil type is shown and that other relatively thin, interbedded soil types are also present.
4. Datum is mean sea level.

HORIZONTAL SCALE

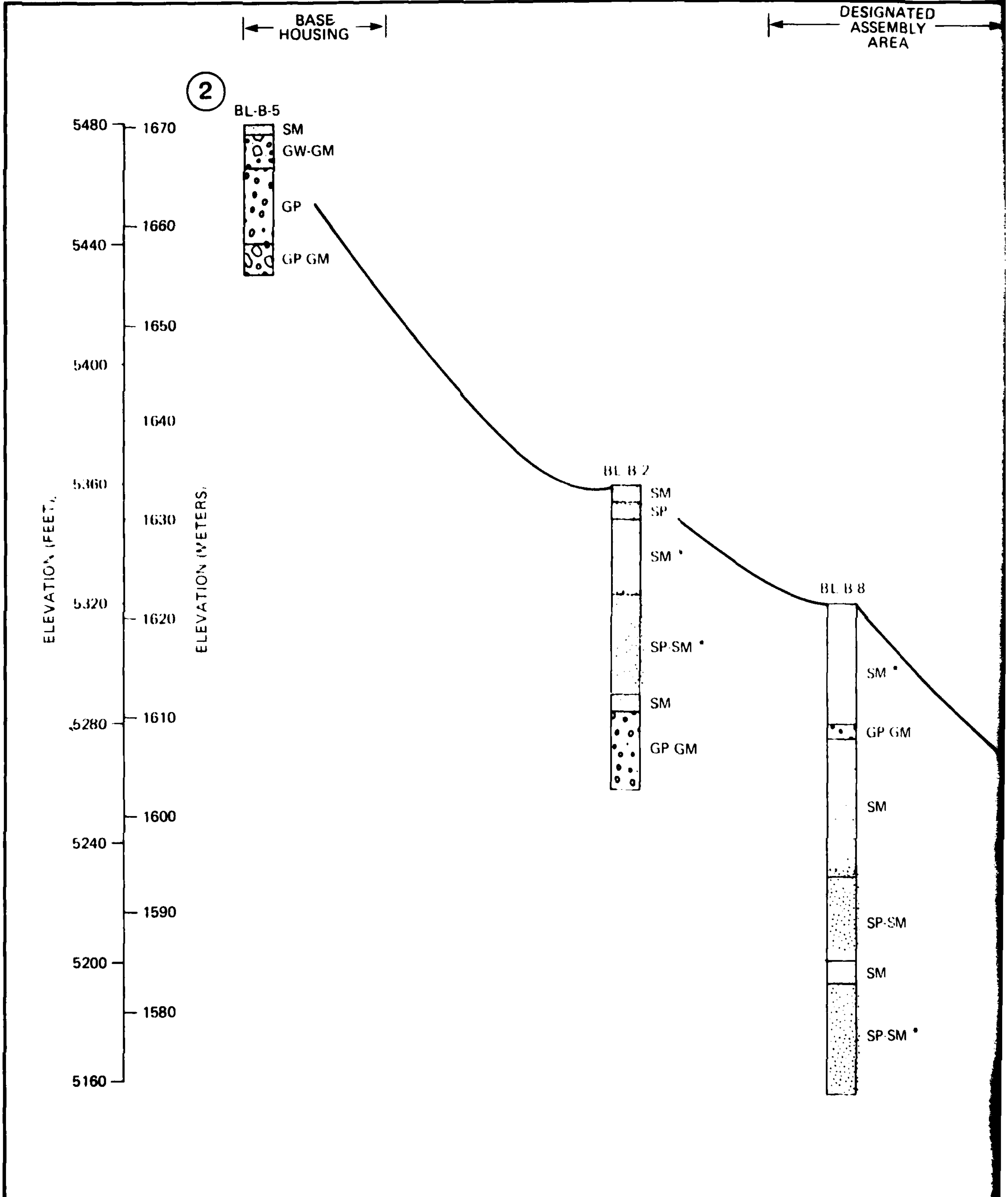


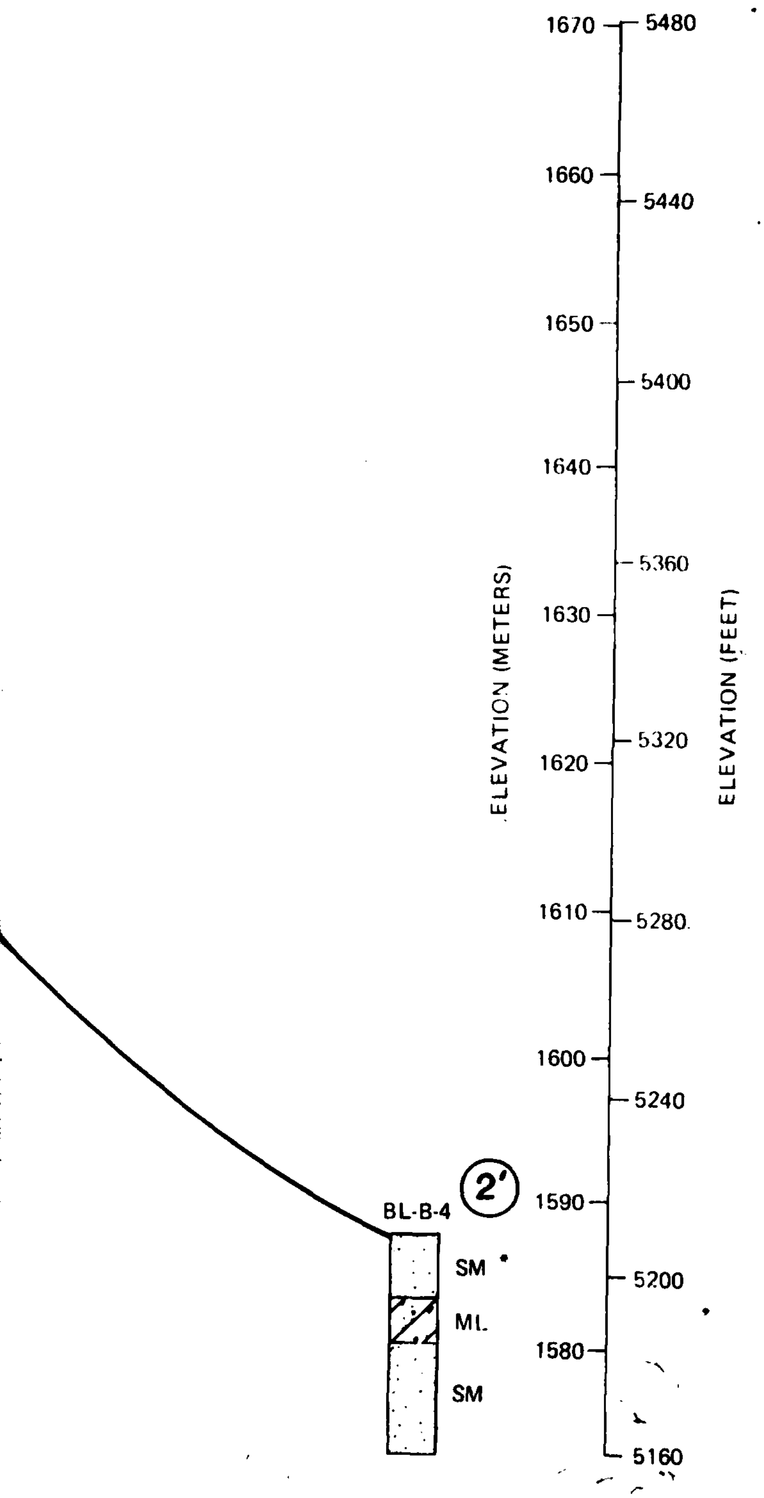
VERTICAL EXAGGERATION IS 66X

SOIL PROFILE 1–1' OPERATIONAL BASE SITE BERYL, UTAH	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE – BMO	FIGURE 6 - 1

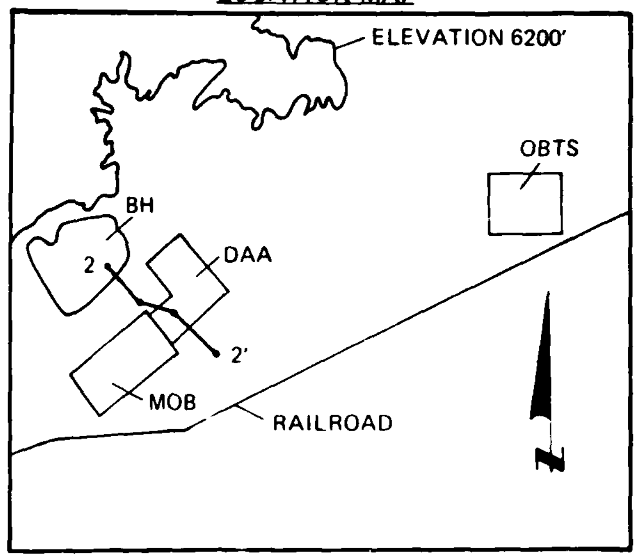
FUGRO NATIONAL, INC.

3


BASE HOUSING
DESIGNATED ASSEMBLY AREA
2
BL-B-5
SM
GW-GM
GP
GP GM
BL B 2
SM
SP
SM *
SP-SM *
SM
GP GM
BL B 8
SM *
GP GM
SM
SP-SM
SM
SP-SM *
ELEVATION (FEET)
ELEVATION (METERS)
5480
5440
5400
5360
5320
5280
5240
5200
5160
1670
1660
1650
1640
1630
1620
1610
1600
1590
1580



LOCATION MAP



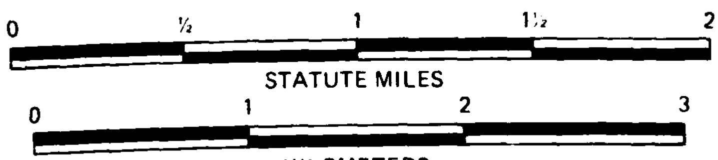
EXPLANATION

B - Boring
T - Trench
P - Test Pit

NOTES:

1. Ground surface elevations shown at activity locations are approximate.
2. Soil types shown adjacent to soil column are based on Unified Soil Classification System (USCS) and are explained in the appendix.
3. * - indicates that only the predominate soil type is shown and that other relatively thin, interbedded soil types are also present.
4. Datum is mean sea level.

HORIZONTAL SCALE



VERTICAL EXAGGERATION IS 66X

SOIL PROFILE 2 2' OPERATIONAL BASE SITE BERYL, UTAH	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE – BMO	FIGURE 6 - 2
FUGRO NATIONAL, INC.	

SOIL DESCRIPTION			SAND	SILT AND CLAY
			Gravelly SAND, Silty SAND, Clayey SAND	Sandy SILT, SILT, Silty CLAY, CLAY
USCS SYMBOLS			SP, SW, SM, SC	ML, MH, CL, CH
SHEAR STRENGTH DATA				
UNCONFINED COMPRESSION		Su-ksf(kN/m^2)	0.1 - 6.9 (5 - 330) [16]	1.9 - 2.9 (91 - 139) [2]
TRIAXIAL COMPRESSION		c-ksf(kN/m^2),ϕ°	0.0, 44° (0) [1]	0.3 - 1.0 , 32°- 39° (14 - 48) [3]
DIRECT SHEAR	Natural Moisture Content 5.8% to 21.9%	c-ksf(kN/m^2)	0.1 - 1.9 (5 - 91) [39]	0.9 (43) [3]
		ϕ°	33° - 48° [39]	40° [3]
	Soaked Moisture Content 17.5% to 26.5%	c-ksf(kN/m^2)	0.0 - 2.0 (0 - 96) [26]	0.0 (0) [3]
		ϕ°	31° - 46° [26]	39° [3]
CONSOLIDATION	Natural Moisture Content 6.1% to 17.1%	m_v ft^2/k(m^2/MN)	0.0009 - 0.0043 (0.0190 - 0.0898) [6]	0.0009 - 0.0055 (0.0190 - 0.1149) [3]
	Soaked Moisture Content 10.1% to 17.7%	m_v ft^2/k(m^2/MN)	0.0011 - 0.0052 (0.0230 - 0.1086) [3]	0.0031 - 0.0118 (0.0647 - 0.2465) [2]

NOTES: [ ] - NUMBER OF TESTS PERFORMED
NDA - NO DATA AVAILABLE (INSUFFICIENT DATA)

CHARACTERISTICS OF SUBSURFACE SOILS
OPERATIONAL BASE SITE
BERYL, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

TABLE 6-2

FUGRO NATIONAL, INC.

6.2.2 Foundation Recommendations

In order to provide preliminary foundation recommendations for the various facilities in the proposed Operational Base, the structures are grouped into three categories according to their anticipated column loads. These loads are as follows:

- Structures with light column loads (less than 50 kips [23 tonnes]) - Structures with one or two stories
- Structures with medium column loads (50 to 200 kips [22.7 to 90.7 tonnes]) - Structures with more than two stories, or light structures with long spans between columns
- Structures with heavy column loads (greater than 200 kips [90.7 tonnes]) - All structures with more than two stories, warehouses, and other heavy structures

The typical subsurface conditions in the OB site as revealed by the borings, trenches, and test pits are shown in soil profiles, Figures 6-1 and 6-2.

The northeastern three quarters of the MOB, and the entire DAA, OBTS, and BH areas are underlain by alluvial gravel and sand having a minimum thickness of 80 feet (24.4 m). The density of this material is between medium dense and very dense, with moderate to high shear strength and very low to medium compressibility. Shallow spread, combined, or continuous footings will be suitable for the foundations of buildings in these areas. The minimum foundation depth should be 2 to 3 feet (0.6 to 0.9 m) below final grade on the undisturbed gravel/sand. This minimum depth is determined from frost heave considerations

which will be discussed in Section 6.5. The recommended net allowable bearing pressures for the footings are as follows:

Column Load	Minimum Foundation Depth Below Final Grade feet (meters)	Net Allowable Bearing Pressure, q_a ksf (kN/m^2)
Light	2 to 3 (0.6 to 0.9)	2 to 4 (96 to 192)
Medium	3 to 4 (0.9 to 1.2)	4 to 7 (192 to 336)
Heavy	4 to 5 (1.2 to 1.5)	6 to 9 (228 to 432)

Where loose gravel, sand lenses, or layers are located below the foundation level, they should either be densified by conventional compaction methods or the bearing pressures should be reduced.

Exceptions to the above recommendations exist in the southwestern quarter of the MOB area. According to field mapping, this area is covered by mainly fine-grained, young alluvial fan deposits. It was not possible to perform any engineering activities (borings, trenches, test pits, or cone penetrometer tests) in this area due to access restrictions. For preliminary design purposes, the subsurface conditions in this area are generalized from regional considerations, field mapping, and borings outside the area.

o Approximately 1 mi^2 (2.6 km^2) of the southwestern portion of the MOB is covered by a fine-grained young alluvial fan deposit (A5yf) (Drawing 5-1). It appears that most of this area is underlain by approximately 2 to 5 feet (0.6 to 1.5 m) of fine-grained soils overlying gravel/sand. Experience with similar alluvial fan deposits indicates that the consistency of the fine-grained soils is probably between firm and stiff and that the gravel/sand is probably in a medium-dense to dense condition. In this case, shallow foundations founded on the gravel/sand, as discussed in the previous section, can

be used to support the structures. Alternatively, the fine-grained materials can be replaced with compacted granular materials. Footings can then be founded at shallower depths on the compacted granular material.

o A somewhat different condition is interpreted to exist in approximately 0.5 mi^2 (1.3 km^2) in the extreme southern corner of the MOB. This area is covered by the young alluvial fan (A5yf) deposits and the mixed young alluvial fan and lake (A5ys/A4of) deposits (Drawing 5-1). Here, a complex geologic condition exists due to the convergence of two young alluvial fans. The subsurface conditions are interpreted to consist of interbedded coarse- and fine-grained soils for a thickness of greater than 50 feet (15 m). Shallow spread, combined, or continuous footings will also be suitable for the foundations of buildings in this area. However, because of the fine-grained soils present in the subsurface, the net allowable bearing pressures should be lower than those recommended for the structures in the majority of the OB site.

Approximately 1 mile (1.6 km) east of the northeast corner of the MOB, a sample of sandy silt, taken from a depth of 19 feet (5.8 m) below the ground surface, was found to exhibit a significant increase of settlement upon saturation. Although no soils within any of the activity centers showed a similar behavior, their possible occurrence should be determined by future investigations.

6.2.2.1 Foundation for Missile Assembly Building (MAB)

The deeper part of the MAB is a pit, 50 feet (15 m) deep and 80 feet (24 m) by 35 feet (11 m) in plan, with an 8-foot (2.4-m) diameter shaft which extends 80 feet (24 m) below the bottom of the pit. The MAB is located in the DAA which is underlain by the gravel/sand of the alluvial fan deposits. Although the foundation load is high, the net bearing pressures on the soils at the bottom of the pit will be small and should not cause bearing or settlement problems. Spread or continuous footings

placed at the bottom of the pit can be used to support this part of the structure.

The sides of the pit excavation may be either sloped or vertical. In the latter case, an adequately designed, lateral-support system would be necessary. The lateral earth pressure from the adjacent soil and the pressures induced by shallow footings of the other parts of the structure should be considered for designing the support system.

The excavation for the shaft beneath the pit could be accomplished by using a large-diameter earth auger. Lateral-support methods such as reinforced gunite, shotcrete, or liners could be used to support the walls of the shaft during excavation and construction.

6.3 ROADS AND RUNWAY

6.3.1 Roads

The present layout (Drawing 4-1) shows that most of the roads connecting the major activity centers will be constructed on alluvial fan deposits consisting of gravel and sand. The results of CBR tests on these soils indicate that the gravel will provide good to excellent support as a subgrade, and the sand will provide fair to good support as a subgrade. Only moderate compactive effort for subgrade preparation will be required for most roads on the alluvial fans. The young alluvial fan deposits and young fluvial deposits containing gravelly sand, silty sand, and clayey sand will probably require more compactive effort than the other soils.

Figure 6-3 shows that the CBR value of the sand, for a given relative compaction, varies substantially. The reasons for this are the variations in gradation and fines content. As the fines content of the gravel and sand increases, the CBR value used for design should be lowered.

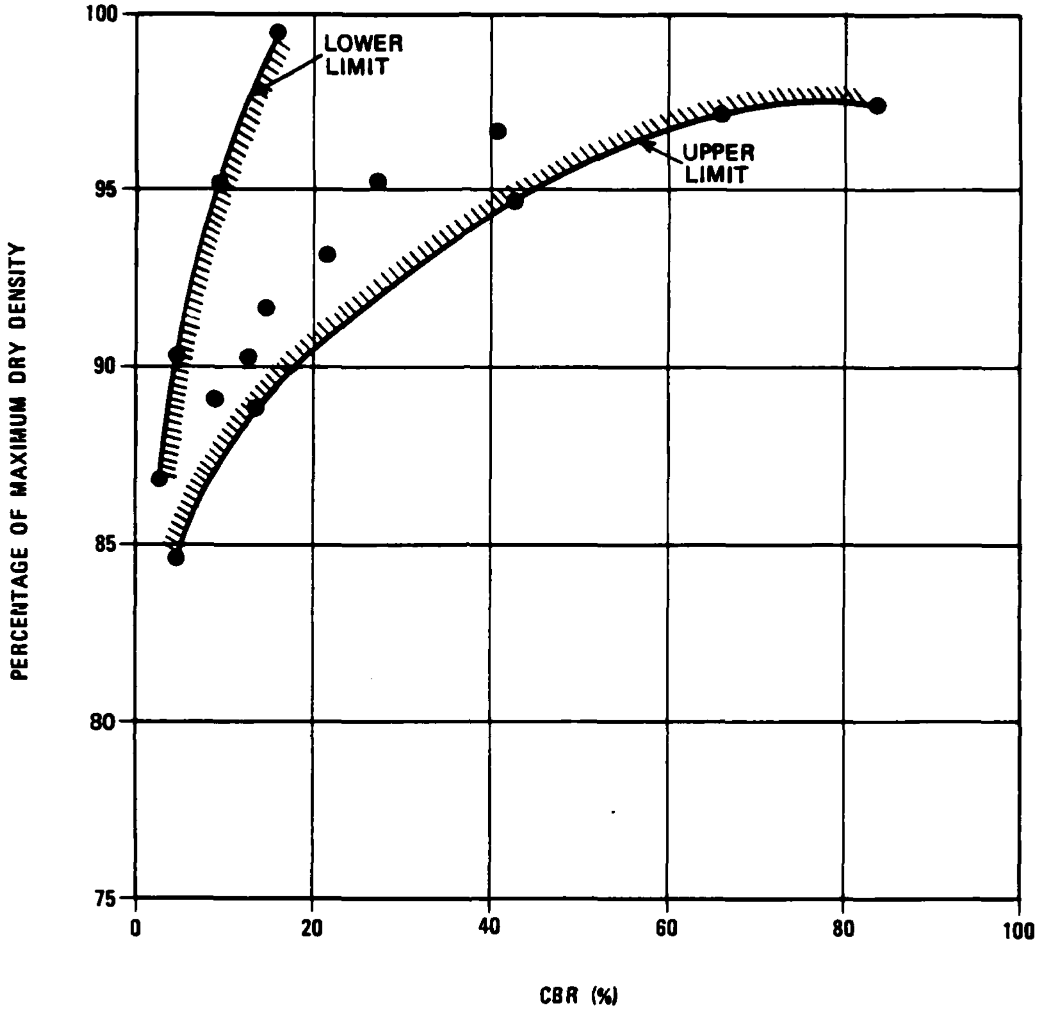
Due to the frost heave susceptibility of the silty sand, this soil may require replacement (by coarse granular material) or modification (by the addition of cement, lime, or chemical stabilizing agents) to provide a suitable subgrade for the roads.

6.3.2 Runway

As presently proposed (Drawing 4-1), the planned runway will trend along the southeastern edge of the MOB. The surficial soils of the younger- and intermediate-age alluvial fan deposits in this area consist of silty sand. As described in the previous section (6.3.1), this material will provide fair to good support as a subgrade. However, due to consideration of the frost-heave susceptibility of silty sand, this material may require replacement or modification to provide acceptable subgrade support for the runway.

6.4 SLOPE STABILITY

The ground surface of most of the OB site has a slope of less than 3 percent (Drawing 5-2); however, steeper slopes (greater than 10 percent) occur in the BH area. Our observations indicate that there is no evidence of any landslide or major "hillside mass wasting" in either the BH or any other area of



CBR VALUES FOR SAND
OPERATIONAL BASE SITE
BERYL, UTAH

MX SITING INVESTIGATION

DEPARTMENT OF THE AIR FORCE — BMO

FIGURE 6-3

FUGRO NATIONAL, INC.

the OB site. All natural slopes in this OB site appear to be stable.

Most temporary excavations in the granular alluvial deposits will require slopes between 1/2:1 (horizontal:vertical) in the cemented gravelly materials and 1 1/2:1 in the cleaner sandy deposits. Permanent slopes should be flatter and designed according to the local soil conditions.

Slopes for excavations in the fine-grained soils of either the alluvial fan or lacustrine deposits will have a wide range because of the variations in the strength of the soils. It is expected that temporary cuts can be made at a slope of 1/2:1. Flatter slopes may be required locally in areas of relatively weak soils. Permanent slopes will have to be designed based on the results of site-specific investigations.

Significant erosion control will be needed for most of the slopes except those in the gravelly deposits. On some slopes, it may be necessary to divert runoff or plant vegetative cover.

6.5 CONSTRUCTION CONSIDERATIONS

Construction aspects such as site preparation, excavatability and compactability of the soils, chemical attack, and frost attack are briefly discussed in this section.

o <u>Site Preparation</u> - Due to the potential for deflation of land once the vegetative cover is removed, stripping should be confined to areas where it is required for construction. In areas where stripping is required, and in areas of undisturbed, nonvegetated windbown sand deposits, new vegetative cover should be provided.

- Slab on Grade - The thickness of the loose coarse-grained surficial soils ranges from 1 to 3 feet (0.3 to 0.9 m). These soils should be densified before construction of any slabs-on-grade. The depth of densification will depend on the design load of the floor slab. In areas of fine-grained surficial soils, they should be compacted and then covered by 6 to 12 inches (15 to 30 cm) of compacted granular material prior to construction of the slab.

- Excavation and Compaction - The seismic velocity of the top 5 feet (1.5 m) of the subsurface soils ranges between 1230 and 2100 fps (375 and 640 mps). Based on the range of the seismic velocities and on observations made during backhoe trench and test pit excavations, conventional equipment could be used for shallow excavations in all areas except portions of the BH area. In the BH area where Stage III and IV caliche cementation and shallow rock exist, ripping and/or blasting may be required for excavation. For most of the shallow excavations, temporary lateral support is not required. Compactability of the gravel and sand of the alluvial fan deposits is good. A wide range of compaction equipment would be suitable for compacting these soils. The most efficient type would be vibratory rollers.

  Compactability of the fine-grained lake deposits is poor to fair. Compaction of these soils would be most efficiently performed by rubber-tired or sheepsfoot rollers.

- Sulfate Attack on Concrete - Results of chemical tests indicate that the potential for sulfate attack of the soils on concrete will be "negligible" (maximum sulfate content 0.14 percent). Although none were observed, it is possible for gypsiferous materials to be present in the lake sediments. Since the high sulfate content of such materials is damaging to concrete, any future studies of this site should include tests for the presence of sulfate in the lake sediments.

- Frost Attack - The gravel and gravelly sand of the alluvial fan deposits and the lean silty clay and clay of the lake deposits are considered to be moderately susceptible to frost heave. Footings in these soils should be founded at least 2 feet (0.6 m) below the final grade. The silty sand of the alluvial fan deposits and the sandy silt and silt of the lake deposits are considered to be severely susceptible to frost heave. Footings in these soils should be founded at least 3 feet (0.9 m) below the final grade.

6.6 AGGREGATE SOURCES

Aggregate materials are commonly derived from both basin-fill and rock sources. High-quality rock sources are generally more

readily available than high-quality basin-fill sources. However, because of the higher cost of developing aggregates from rock sources, it is usually more economical to develop basin-fill sources.

An ideal basin-fill source for concrete aggregate should be composed of well-graded, hard, durable, subangular to subrounded particles. An ideal rock source for concrete aggregate should be easily accessible with favorable bedding and jointing patterns. It should also possess chemical and physical characteristics that, upon mining and crushing-down, produce optimum-sized, equidimensional particles. Physical and chemical properties for basin-fill and rock road-base aggregate sources are similar but less stringent than those for concrete aggregate sources.

The principal source of potentially suitable coarse and fine aggregates are the alluvial fans (A5og, A5ig, A5yg/A5ys) flanking the southern Needle Range in the vicinity of the proposed Base Housing area. Derived from basalt and ash-flows of intermediate composition, these deposits are typically heterogeneous mixtures of boulders, cobbles, gravel, sand, silt, and clay. Field observations indicate that materials eroded from the ash-flow sources may contain high percentages of low density, altered volcanic rock fragments that could be alkali reactive.

Another major source of potentially suitable coarse and fine aggregates are the alluvial fan deposits bordering the southern

Wah Wah Mountains, northeast of the proposed site. Limited test data indicate that the fine aggregate fraction of these deposits may not be acceptable for concrete.

Widespread stream-channel deposits (A1) associated with secondary and primary ephemeral streams may supply additional coarse and fine aggregates. They are heterogeneous mixtures that vary from boulders to silt and clay depending on their location in the valley area. The most durable materials are found along streams which drain the most acceptable rock sources.

Potential sources of suitable crushed rock may be found in the Cenozoic volcanics of the southern Needle Range. Directly north of the proposed Base Housing is a Tertiary vesicular, very hard basalt; limited laboratory testing indicates that the basalt has acceptable abrasion and soundness properties. Although not yet tested for alkali reactivity, the volcanic glass in these rocks may represent a potential problem. Quaternary basalt flows north of the OBTS have not been tested, but field observations indicate that these rocks could supply additional crushed rock aggregates.

Other potential sources of crushed rock may be located in the Cenozoic basic to acidic volcanic flows of the northern Bull Valley Mountains area (approximately 30 miles [48 km] south of the site) and the Paleozoic carbonate rocks of the southern Wah Wah Mountains (approximately 12 miles [19 km] north of Lund).

In general, sufficient volumes of coarse and fine aggregates required for concrete and road-base construction purposes appear

to be available from a variety of basin-fill and rock sources within or near the study area. However, these conclusions are based on field observations with limited laboratory test data. A detailed aggregate laboratory testing program (i.e., siev analysis, Los Angeles abrasion, soundness, potential alkal reactivity, and specific gravity and absorption) is recommended before precise estimates on the quality of aggregates can be determined.

7.0 RECOMMENDATIONS FOR FUTURE STUDIES

Additional detailed studies should be made before final layout and design of the various activity centers in the proposed Operational Base. Further studies are recommended for better definition the hazards due to 1) flooding, 2) faulting and seismicity, 3) subsidence, and 4) sand-dune migration and reactivation. Future studies are also recommended to develop more specific and precise foundation-design criteria for the individual activity centers and to identify the extent and chemical and physical characteristics of the available aggregate resources. These recommended future studies are discussed in the following sections.

7.1 FLOODING POTENTIAL

An assessment of the potential for flooding at the activity centers should be made, including the following determinations:

- o Volume of storm runoff;
- o Peak flood discharge;
- o Flow velocities; and
- o Maximum probable flood for the predicted lifetime of the facilities.

7.2 FAULTS AND SEISMICITY

We recommend the following detailed seismic risk analysis:

- o Seismotectonic setting and its significance;
- o Seismic history of the region;
- o Local and regional fault relationships;
- o Fault parameters (including length, projections, nature of displacement, etc.);

- o Activity ratings (ages of last movement);
- o Empirical relationships of fault length-scarp height to credible and probable maximum magnitudes;
- o Probability study for future earthquakes; and
- o Seismic design of structures.

We also recommend that trenches be excavated across the major faults and lineaments (Section 5.5.2) that are located in the vicinity of the planned activity centers. These data will aid in determining rates of fault movement, age of last movement, minimum fault ages, and seismic design.

7.3 SUBSIDENCE

A precautionary assessment of the potential for land subsidence due to ground-water withdrawal is recommended. This study should include:

- o Estimates of ground-water recharge and current and future withdrawal requirements; and
- o Determination of the amount of historic ground-water level decline and the correlation between areas of withdrawal and known instances of ground cracking.

7.4 SAND DUNES

A detailed study of the migration and potential for reactivation of dunes in the site areas should be made and include the following determinations:

- o Rate of migration;
- o Prominent regional and local wind directions; and
- o The possible relationship between disturbance of the ground surface at the proposed activity centers and the potential for dune reactivation.

7.5 FOUNDATION DESIGN

The results of the present study indicate that detailed foundation investigations should be performed after building locations have been determined. It is recommended that the field investigations include borings, trenches, test pits, and cone penetrometer tests. Cone penetrometer tests spaced between borings will be very helpful in correlating soil conditions from one boring to the next. The depth of investigation will depend on the depth of influence of the structure. The field investigation should be geared to:

- o Determine the soil profile for each building location; and
- o Obtain soil samples for laboratory testing.

Additional detailed laboratory tests should be performed to determine the strength and compressibility properties of the soils. In particular, laboratory tests should be performed to determine the occurrence of soil deposits subject to increased settlement upon saturation. Following the field and laboratory investigations, detailed analyses will be necessary to determine allowable bearing pressures for the various structures considering the type of structure, loading, and its tolerance to settlement.

7.6 AGGREGATE RESOURCES

A detailed aggregate study should be performed to delineate the most promising aggregate sources and to determine their chemical and physical characteristics. The study should consist of:

- o Field geologic mapping;
- o Excavation of test pits; and

- o Obtaining samples for laboratory testing.

The field work should be planned so that the lateral and vertical extent of the potential aggregate sources can be determined. To determine the quality of the aggregate, we recommend the following tests:

- o Sieve analysis, Los Angeles abrasion, soundness, potential reactivity, specific gravity, and absorption.

In addition, we recommend that trial mixes of concrete using these aggregates be made to determine the concrete strength and related properties.

8.0 REFERENCES CITED

Anderson, L. W., and Miller, D. G., 1979, Quaternary fault map of Utah: Fugro National, Inc. and Utah Geological and Mineralogic Survey, 35 p., (1:500,000 scale).

Conrad, O. G., 1969, Tertiary volcanic rocks of the Needles Range, western Utah: Utah Geological and Mineral Survey, Spec. Studies 29.

Day, R., 1980, City Recorder, Enterprise, Utah, personal communication.

Donovan, N.C., 1973, A statistical evaluation of strong ground motion data including the February 9, 1971 San Fernando earthquake: Proc. Fifth World Conference Earthquake Engineering.

Hamblin, W. K., and Best, M. G., 1970, The western Grand Canyon district: Utah Geological Society Guidebook to the Geology of Utah, p. 23.

Hintze, L. F., 1963, Geologic map of southwestern Utah: Department of Geology, Brigham Young University (1:250,000 scale).

Housner, G. W., 1965, Intensity of earthquake ground shaking near the causative fault: Proc. Third World Conference Earthquake Engineering, v. 1, p. 94-109.

Iron County Clerk, 1981, Parowan, Utah, personal communication.

Luedke, R. G., and R. L. Smith, 1979, map showing distribution, composition and age of Late Cenozoic volcanic centers in Colorado, Utah, and southwestern Wyoming: U.S. Geological Survey, Map I-1091-B.

Melhorn, W. M. and Trexler, D. T., 1977, The Maria effect: equilibrium and activation of aeolian processes in the Great Basin of Nevada, in Doehring. D. O., ed., Geomorphology in Arid Regions: Fort Collins, Colorado, p. 271-272.

Morrison, R. B., 1966, Predecessors of great Salt Lake, in Stokes, W. L., ed. the Great Salt Lake (guidebook to the geology of Utah 20): Utah Geological Survey, p. 77-104.

Mower, R. W., and Cordova, R. M., 1973, Ground-water in the Milford area, Utah, in Hintze, L. F., and Whelan, J. A., eds., Geology of the Milford Area: Utah Geological Association Publication 3, p. 63-71.

Schnabel, P. B. and Seed, H. B., 1973, Acceleration in rock for earthquakes in the western United States: Seismological Society of America Bulletin, v. 63, no. 2, p. 501-516.

Slemmons, D. B., 1977, State-of-the-art for assessing earthquake hazards in the United States; report 6: in Faults and Earthquake Magnitude: U.S. Army Waterways Experiment Station Misc. Paper 5-73-1.

Smith, R. B., and Sbar, M. L., 1974, Contemporary tectonics and seismicity of the western United States with emphasis on the Intermountain Seismic Belt: Geological Society of America Bulletin, v. 85, p. 1205-1218.

Swan, F. H., III, Schwartz, D. P., and Cluff, L. S., 1980, Recurrence of surface faulting and moderate to large magnitude earthquakes on the Wasatch fault zone at the Kaysville and Hobble Creek sites, Utah: U.S. Geological Survey Open-File Report 80-401.

Utah Geological and Mineral Survey, 1980, Geothermal Resources of Utah, map scale 1:500,000.

APPENDIX

A1.0 GLOSSARY OF TERMS

ACIDIC ROCK - A descriptive term applied for those igneous rocks that contain 66 percent or more of silica, e.g., rhyolite.

ACTIVE FAULT - A fault which has had surface displacement within Holocene time (about the last 12,000 years).

ACTIVITY NUMBER - A designation composed of the valley abbreviation followed by the activity type and a unique number; may also be used to designate a particular location in a valley.

AGGREGATE - Granular material such as sand, gravel, crushed stone, and iron-blast furnace slag used for constructional purposes.

ALLOWABLE BEARING PRESSURE - The maximum foundation pressure to the soil which will not induce structural damage to the super-structure. The net allowable bearing pressure is the allowable bearing pressure less the original overburden pressure.

ALLUVIAL FAN DEPOSITS - Alluvium deposited by a stream or other body of running water (including mud and debris flows) as a sorted or semisorted sediment in the form of a cone or fan at the base of a mountain slope.

ALLUVIUM - A general term for unconsolidated clay, silt, sand, gravel, and boulders deposited during relatively recent geologic time by a stream or other body of running water (including mud and debris flows) as a sorted or semisorted sediment in the bed of a stream or on its flood plain or delta, or as a cone or fan at the base of a mountain slope.

ASH FLOW - A density current, generally a highly heated mixture of volcanic gases and ash, traveling down the flanks of a volcano or along the surface of the ground.

ATTERBERG LIMITS - A general term applied to the various tests used to determine the various states of consistency of fine-grained soils. The four states of consistency are solid, semisolid, plastic, and liquid.

Liquid Limit (LL) - The water content corresponding to an arbitrary limit between the liquid and plastic states of consistency of a soil (ASTM D 423-66).

Plastic Limit (PL) - The water content corresponding to an arbitrary limit between the plastic and the semisolid states of consistency of a soil (ASTM D 424-59).

Plasticity Index (PI) - Numerical difference between the liquid limit and the plastic limit indicating the range of

moisture content through which a soil-water mixture is plastic.

BASIC ROCK - General descriptive term for those igneous rocks that are comparatively low in silica (45 to 52 percent), e.g., basalt.

BASIN-FILL MATERIAL/BASIN-FILL DEPOSITS - Heterogeneous detrital material deposited in a sedimentary basin.

BEDROCK - A general term for the rock, usually solid, that underlies soil or other unconsolidated surficial material. The term is also used here to include the rock composing the local mountain ranges.

BORING - A method of subsurface exploration whereby an open hole is formed in the ground through which soil sampling or rock drilling may be conducted.

BOULDER - A detached rock mass having a diameter greater than 10 inches (256 mm), being somewhat rounded or otherwise distinctively shaped by abrasion in the course of transport.

BRECCIA - A coarse-grained clastic rock composed of angular broken rock fragments held together by a mineral cement or in a fine-grained matrix.

BULK SAMPLE - A disturbed soil sample (bag sample) obtained from cuttings brought to the ground surface by a drill rig auger or obtained from the walls of a trench or test pit excavation.

c - Cohesion (Shear strength of a soil not related to interparticle friction).

CALCAREOUS - Containing calcium carbonate; presence of calcium carbonate is commonly identified on the basis of reaction with dilute hydrochloric acid.

CALICHE - In general, secondary calcium carbonate cementation of unconsolidated materials occurring in arid and semiarid areas.

CALIFORNIA BEARING RATIO (CBR) - The ratio (in percent) of the resistance to penetration developed by a subgrade soil to that developed by a specimen of standard crushed rock-base material (ASTM D 1883-73). During the CBR test, the load is applied on the circular penetration piston (3 in^2 [19 cm^2] base area) which is penetrated into the the soil sample at a constant penetration rate of 0.05 inch/minute (1.2 mm/ min). The bearing ratio reported for the soil is normally the one at 0.1-inch (2.5-mm) penetration.

CENOZOIC - An era of geologic time from the beginning of the Tertiary period (about 65 million years ago) to the present.

CLAST - An individual constituent, grain, or fragment of a sediment or rock produced by the mechanical weathering (disintegration) of a larger rock mass.

CLAY - Fine-grained soil (passes No. 200 sieve [0.074 mm] that can be made to exhibit plasticity within a range of water contents and that exhibits considerable strength when air dried.

CLAY SIZE - That portion of the soil finer than 0.002 mm.

CLOSED BASIN - A catchment area draining to some depression or lake within its area from which water escapes by evaporation or infiltration into the subsurface.

COARSE-GRAINED (or granular) - A term which applies to a soil of which more than one-half of the soil particles, by weight, are larger than 0.074 mm in diameter (No. 200 U.S. sieve size).

COARSER-GRAINED - A term applied to alluvial fan deposits which are predominantly composed of material (cobbles) larger than than 3 inches (76 mm) in diameter.

COBBLE - A rock fragment, larger than a pebble and smaller than a boulder, having a diameter between 3 and 10 inches (64 and 256 mm), being somewhat rounded or otherwise modified by abrasion in the course of transport.

COMPACTION TEST - A type of test to determine the relationship between the moisture content and density of a soil sample which is prepared in compacted layers at various water contents (ASTM D 1557-70).

COMPRESSIBILITY - Property of a soil pertaining to its susceptibility to decrease in volume when subjected to load. See m_v for definition of coefficient of volume compressibility.

CONE PENETROMETER TEST - A method of evaluating the in-situ engineering properties of soil by measuring the penetration resistance developed during the steady slow penetration of a cone (60^{o} apex angle, 2.3-in^2 [15-cm^2] projected area) into soil.

Cone resistance or end bearing resistance, q_c - The resistance to penetration developed by the cone, equal to the vertical force applied to the cone divided by its horizontally projected area.

Friction resistance, f_s - The resistance to penetration developed by the friction sleeve, equal to the vertical force applied to the sleeve divided by its surface area. This resistance consists of the sum of friction and adhesion.

Friction ratio, f_R - The ratio of friction resistance to cone resistance, f_s/q_c, expressed in percent.

CONGLOMERATE - A coarse-grained clastic sedimentary rock composed of fragments larger than 2 mm in diameter. The consolidated equivalent of a gravel.

CONSISTENCY - The relative ease with which a soil can be deformed.

CONSOLIDATION TEST - A type of test to determine the compressibility of a soil sample. The sample is enclosed in the consolidometer which is then placed in the loading device. The load is applied in increments at certain time intervals and the change in thickness is recorded.

DEGREE OF SATURATION - Ratio of volume of water in soil to total volume of voids.

DIRECT SHEAR TEST - A type of test to measure the shear strength of a soil sample where the sample is forced to fail on a predetermined plane.

DISSECTION/DISSECTED - The cutting of stream channels into soil units by the movement (or flow) of water.

DRY UNIT WEIGHT/DRY DENSITY - Weight per unit volume of the solid particles in a soil mass.

EPHEMERAL STREAM - A stream or reach of a stream that flows briefly only in direct response to precipitation in the immediate locality and whose channel is at all times above the water table.

EXHUMATION - Uncovering or exposure by erosion of a pre-existing surface.

EXHUMED - Resurrected.

FANGLOMERATE - Sedimentary rock deposited in an alluvial fan and later cemented into a firm rock.

FAULT - A fracture or a zone of fractures along which there has been displacement of the sides relative to one another parallel to the fracture.

FINE-GRAINED - A term which applies to a soil of which more than one-half of the soil particles, by weight, are smaller than 0.074 mm in diameter (passing the No. 200 U.S. size sieve).

FLOOD-PLAIN DEPOSITS - Sediment deposited by river water that was spread out over the relatively smooth land adjacent to a river channel, constructed by the present river in its existing regimen and covered with water when the river overflows its bank.

FLUVIAL DEPOSITS - Material produced by river action; generally loose, moderately well-graded sands and gravel.

FOOTING - (Spread, combined, continuous, or strip) - If various parts of the structure are supported individually, the individual supports are known as spread footings, and the foundation is called a footing foundation. A footing that supports a single column is called an individual footing; one that supports a group of columns is a combined footing; and one that supports a wall is a continuous footing.

FUGRO DRIVE SAMPLE - A 2.50-inch-(6.4-cm) diameter soil sample obtained from a drill hole with a Fugro drive sampler. The Fugro drive sampler is a ring-lined barrel sampler containing 12 1-inch- (2.54-cm) long brass sample rings. The sampler is advanced into the soil using a drop hammer.

GEOMORPHOLOGY - The study, classification, description, nature, origin, and development of present landforms and their relationships to underlying structures and of the history of geologic changes as recorded by these surface features.

GRAIN-SIZE ANALYSIS (GRADATION) - A type of test to determine the distribution of soil particle sizes in a given soil sample. The distribution of particle sizes larger than 0.074 mm (retained on the No. 200 sieve) is determined by sieving, while the distribution of particle sizes smaller than 0.074 mm is determined by a sedimentation process, using a hydrometer.

GRAVEL - Particles of rock that pass a 3-inch (76.2-mm) sieve and are retained on a No. 4 (4.75 mm) sieve.

HUMMOCKY - A term used to describe a land surface containing abundant rounded or conical knolls, mounds, or dunes.

IGNIMBRITE - Rock formed by the widespread deposition and consolidation of ash flows and nuées ardentes.

INTERMEDIATE ROCK - An igneous rock containing between 52 and 66 percent silica (see acidic and basic rocks), e.g., latite, dacite, trachyte.

JOINTS - Surfaces of fracture or parting in a rock, without displacement.

LACUSTRINE DEPOSITS - Materials deposited in a lake environment.

LIMESTONE - A sedimentary rock consisting chiefly of calcium carbonate.

LINEAMENT - A linear topographic feature of regional extent that is believed to reflect crustal structure.

LIQUID LIMIT - See ATTERBERG LIMITS.

MOISTURE CONTENT - The ratio, expressed as a percentage, of the weight of water contained in a soil sample to the oven-dried weight of the sample.

m_v - Coefficient of Volume Compressibility (the compression of a soil, per unit of original thickness, due to a unit increase of pressure).

N VALUE - Penetration resistance, described as the number of blows required to drive the standard split-spoon sampler for the second and third of three 6-inch (0.15-m) increments with a 140-pound (63.5-kg) hammer falling 30 inches (0.76 m) (ASTM D 1586-67).

NET ALLOWABLE BEARING PRESSURE - See ALLOWABLE BEARING PRESSURE.

OPTIMUM MOISTURE CONTENT - Moisture content at which a soil can be compacted to a maximum dry unit weight by a given compactive effort.

PALEOZOIC - An era of geologic time from about 570 to about 225 million years ago.

PEBBLE - A rock fragment larger than a granule and smaller than a cobble, having a diameter in the range of 1/6 to 2.5 inches (4 to 64 mm), being somewhat rounded or otherwise modified by abrasion in the course of transport.

PERCHED GROUND WATER - Unconfined ground water separated from an underlying main body of ground water by an unsaturated zone.

PITCHER TUBE SAMPLE - An undisturbed, 2.87-inch- (73-mm) diameter soil sample obtained from a drill hole with a Pitcher tube sampler. The primary components of this sampler are an outer rotating core barrel with a bit and an inner stationary, spring-loaded, thin-wall sampling tube which leads or trails the outer barrel drilling bit, depending upon the hardness of the material being penetrated.

PLASTIC LIMIT - See ATTERBERG LIMITS.

PLASTICITY INDEX - See ATTERBERG LIMITS.

PLEISTOCENE - A division of geologic time (epoch) within the Quaternary period (approximately 1.8 to 0.1 million years).

PLIOCENE - A division of geologic time)epoch) within the Quaternary period (approximately 1.8 to 0.1 million years).

PORPHYRITIC - Texture of an igneous rock in which larger crystals (phenocrysts) are set in a finer-grained groundmass.

POTENTIALLY ACTIVE FAULT - A fault which has not moved during the Holocene epoch (0 to 12,000 years) but which shows geologic evidence of recurrent movement during the Pleistocene epoch (12,000 years to 1.8 million years) and remains favorably oriented to the present tectonic stress regime such that it has a potential for movement in the future.

POORLY GRADED - A descriptive term applied to a coarse-grained soil if it consists predominantly of one particle size (uniformly graded) or has a wide range of sizes with some intermediate sizes obviously missing (gap-graded).

RELATIVE AGE - The relationship in age (oldest to youngest) between geologic units without specific regard to number of years.

RESISTIVITY (true, intrinsic) - The property of a material which resists the flow of electric current. The ratio of electric-field intensity to current density.

RHYOLITIC FLOWS - A group of extrusive silicic igneous rocks (the extrusive equivalent of granite).

ROCK UNITS - Distinct rock masses with different characteristics (e.g., igneous, metamorphic, sedimentary).

ROTARY WASH DRILLING - A boring technique in which advancement of the hole through overburden is accomplished by rotation of a heavy string of rods while continuous downward pressure is maintained through the rods on a bit at the bottom of the hole. Water or drilling mud is forced down the rods to the bit, and the return flow brings the cuttings to the surface.

SAND - Soil passing through No. 4 (4.75 mm) sieve and retained on No. 200 (0.075 mm) sieve.

SAND DUNE - A low ridge or hill consisting of loose sand deposited by the wind, found in various desert and coastal regions and generally where there is abundant surface sand.

SEISMIC - Having to do with elastic waves. Energy may be transmitted through the body of an elastic solid as P-waves (compressional waves) or S-waves (shear waves).

SEISMIC LINE - A linear array of travel time observation points (geophones). In this study, each line contains 24 geophone positions.

SEISMIC REFRACTION DATA (deep/shallow) - Data derived from a type of seismic shooting based on the measurement of seismic energy as a function of time after the shot and distance from the shot, by determining the arrival times of seismic waves which have traveled nearly parallel to the bedding in high-velocity layers. This is used to map the depth to such layers.

SETTLEMENT - The subsidence of a structure, caused by compression or movement of the soil below the foundation.

SHEAR STRENGTH - The maximum resistance of a soil to shearing (tangential) stresses.

SILT - Fine-grained soil passing the No. 200 sieve (0.074 mm) that is nonplastic or very slightly plastic and that exhibits little or no strength when air-dried.

SILT SIZE - That portion of the soil finer than 0.02 mm and coarser than 0.002 mm.

SITE - Location of some specific activity or reference point. The term should always be modified to a precise meaning or be clearly understood from the context of the discussion.

SPECIFIC GRAVITY - The ratio of the weight in air of a given volume of soil solids at a stated temperature to the weight in air of an equal volume of distilled water at a stated temperature.

SPLIT-SPOON SAMPLE - A disturbed sample obtained with a split-spoon sampler with an outside diameter of 2.0 inches (5.1 cm). The sample consists of a split barrel which is driven into the soil using a drop hammer.

STREAM CHANNEL DEPOSITS - See Fluvial Deposits.

SUBGRADE - A layer of earth or rock that is graded to receive the foundation of an engineered structure.

SUBSIDENCE - The sudden sinking or gradual downward settling of the earth's surface with little or no horizontal motion.

SULFATE ATTACK - The process during which sulfates (salts of sulfuric acid) contained in ground water cause dissolution and damage to concrete.

TALUS - Rock fragments of any size or shape derived from and lying at the base of a steep rocky slope.

TECTONICS - Related to regional structural features.

TERTIARY - A division of geologic time (period) within the Cenozoic era (65 to approximately 2 million years).

TEST PIT - An excavation made to depths of about 10 feet (3 m) by a backhoe. A test pit permits visual examination of undisturbed material in place.

TRENCH - An excavation by a backhoe to depths of about 14 feet (4.3 m). A trench permits visual examination of soil in place and evaluaton of excavation wall stability.

TRIAXIAL COMPRESSION TEST - A type of test to measure the shear strength of an undisturbed soil sample (ASTM D 2850-70). To conduct the test, a cylindrical specimen of soil is surrounded by a fluid in a pressure chamber and subjected to an isotropic pressure; an additional compressive load is then applied, directed along the axis of the specimen, called the axial load.

Consolidated-drained (CD) Test - A triaxial compression test in which the soil was first consolidated under an all-around confining stress (test chamber pressure) and then compressed (and hence sheared) by increasing the vertical stress. Drained indicates that excess pore water pressures generated by strains are permitted to dissipate by the free movement of pore water during consolidation and compression.

Consolidated-undrained (CU) Test - A triaxial compression test in which essentially complete consolidation under the confining (chamber) pressure is followed by shearing at constant water content.

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS) - A system which determines soil classification for engineering purposes on the basis of grain-size distribution and Atterberg limits.

WATER TABLE - The upper surface of an unconfined body of water at which the pressure is equal to the atmospheric pressure.

WELL GRADED - A soil is identified as well graded if it has a wide range in grain size and substantial amounts of most intermediate sizes.

Definitions were derived from the following references:

American Society for Testing and Materials, 1976, Annual book of ASTM standards, Part 19: Philadelphia, American Society for Testing and Materials, 484 p.

Bates, J.A., R.L. Bates, 1980, Glossary of Geology: American Geological Institute - 2nd Edition.

Gary, M., McAfee, R., Jr., Wolf, C. L., eds., 1972, Glossary of Geology: Washington, D.C., American Geological Institute, 805 p.

Merriam, G., and Merriam, C., 1977, Webster's New Collegiate Dictionary: Springfield, Mass., G. and C. Merriam Co., 1536 p.

Sheriff, R. E., 1973, Encyclopedic Dictionary of Exploration Geophysics: Tulsa, Oklahoma, Society of Exploration Geophysicists, 266 p.

Terzaghi, K., and Peck, R.B., 1967, Soil Mechanics in Engineering Practice: 2nd Edition, New York, Wiley, 729p.

A2.0 ENGINEERING GEOLOGIC PROCEDURES

The geotechnical evaluation of the proposed Operational Base site in Beryl, Utah, was conducted in two major phases, 1) a literature study, data search, and aerial photograph analysis followed by 2) extensive field mapping and field verification of site conditions.

A2.1 REVIEW OF EXISTING DATA

The literature study and data search included a review of all pertinent geological and related literature in the region surrounding the site and discussions with state and county highway and U.S. Weather Bureau personnel to assess potential geologic hazards such as flooding.

Photogeologic analysis was done primarily on color stereo photographs at a scale of 1:25,000. Black and white aerial photographs at a scale of 1:60,000 were used to complement interpretation of data.

A2.2 GEOLOGIC RECONNAISSANCE

The primary objective of the geotechnical field program was to verify and document site conditions and potential hazards. Geologic stations were established at selected locations throughout the site area. The information collected at each station included some or all of the following, depending on local conditions:

- o Detailed geologic descriptions of outcrops, with emphasis on soil types, bedding characteristics, cementation, etc.; and

o Description of surface conditions, including slope gradient, ground cracking, vegetation, evidence for flooding, "hardness" of surface, etc.

Observations from outcrops were supplemented by observations of existing excavations (borrow pits and road cuts) and hand-dug test pits. Data obtained from engineering backhoe trenches, test pits, and hydrologic and engineering borings were incorporated in our geotechnical analysis of the site area.

Geologic mapping was done on 1:25,000-scale color aerial photos with plastic overlays. Data were compiled into four maps and two cross sections. The maps consist of a geologic map, terrain map, depth-to-water map, and geologic hazards map. Data from the aerial photo overlays were transferred directly to 1:24,000 (geologic and terrain) and 1:62,500 (depth to water and geologic hazards) topographic base maps.

The data presented on the terrain map are based on aerial photo and topographic map interpretations combined with representative field measurements. The depth-to-water map is an interpretation based on widely spaced control points (wells) and regional hydrogeologic conditions. Our assessment of the flood and ponding hazards, as presented on the geologic hazards map (Drawing 5-4), is based on aerial photo analysis of existing drainage conditions and limited field observations.

A3.0 GEOPHYSICAL PROCEDURES

A3.1 SEISMIC REFRACTION SURVEYS

A3.1.1 Instruments

Field explorations were performed with a 24-channel SIE Model RS-44 seismic refraction system which consisted of 24 amplifiers coupled with a dry-write, galvanometer-type recording oscillograph. Seismic energy was detected by Mark Products Model L-10 geophones with natural frequency of 4.5 Hz. Geophones were fitted with short spikes to provide good coupling with the ground. Cables with two takeout intervals were used to transmit the detected seismic signal from the geophones to the amplifiers. Time of shot was transmitted from shotpoint to recording system via an FM radio link.

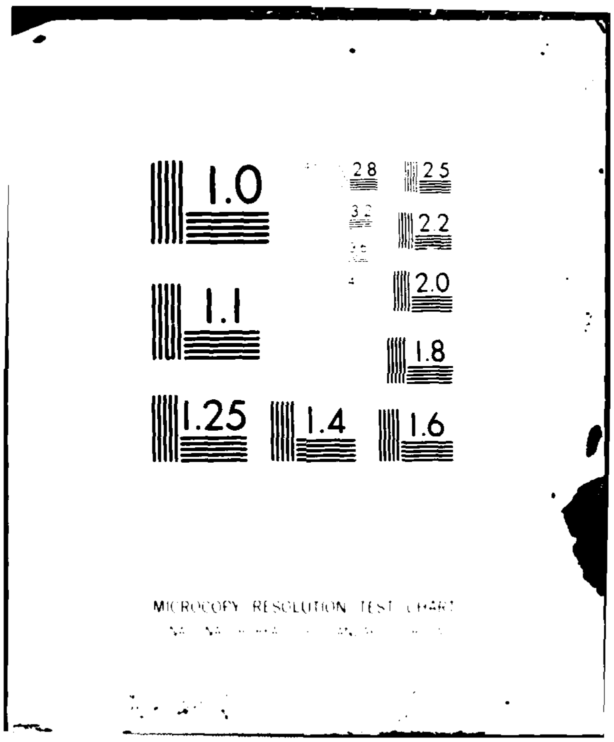
The degree of gain was set on the amplifiers by the instrument operators and was limited by the background noise at the time of the shot. The amplifiers are capable of maximum gain of 1.1 million. The oscillograph placed timing lines on the seismograms at 0.01-second intervals. The timing lines form the basis for measuring the time required for the energy to travel from the shot to each geophone.

A3.1.2 Field Procedures

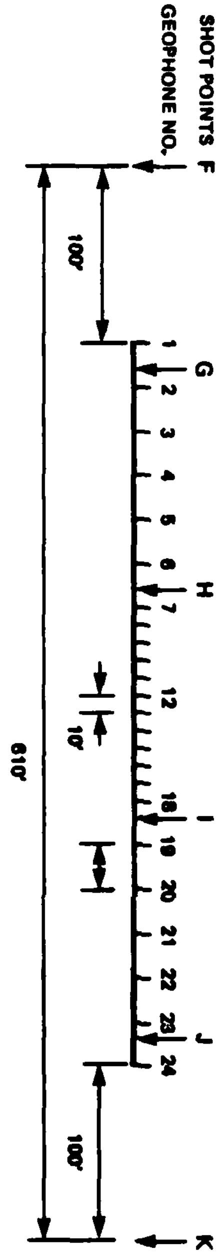
Each seismic refraction line consisted of a single spread of 24 geophones with a distance of 410 feet (125 m) between end points (Figure A3-1). Geophone spacing provided six intervals of 25 feet (7.6 m) at both ends of the line and 11 central intervals of 10 feet (3.0 m). Six shots were made per spread at

AD-A112 529 FUGRO NATIONAL INC LONG BEACH CA F/G 8/7
MX SITING INVESTIGATION. PRELIMINARY GEOTECHNICAL INVESTIGATION--ETC(U)
MAR 81 F04704-80-C-0006
UNCLASSIFIED FN-TR-45-VOL-1 NL

2 of 3
AD A
112 529


1.0
2.8
2.5
3.2
2.2
2.0
1.1
1.8
1.25
1.4
1.6
MICROCOPY RESOLUTION TEST CHART

FN-TR-45



SPREAD CONFIGURATION
SEISMIC REFRACTION LINE
OPERATIONAL BASE SITE
BERYL, UTAH

MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE – BMO	FIGURE A3-1

FUGRO NATIONAL, INC.

20 MAR 81

locations 65 feet (20 m), 190 feet (58 m), and 305 feet (93 m) left and right of the spread center. The recording system was located between geophones 12 and 13.

The explosive used was "Kinestik" which was transported to the site as two nonexplosive components, a powder and a liquid. The components were mixed in the field to make an explosive compound. Charges ranged in size from one-third to five pounds (0.2 to 2.3 kg) and were buried from 1 to 5 feet (0.3 to 1.5 m) deep. Charges were detonated using Reynold's Exploding Bridge Wire (EBW) detonators instead of conventional electric blasting caps. Use of EBWs provides maximum safety against accidental detonation and extremely accurate "time breaks" (instant of detonation). Relative elevations of geophones and shotpoints were obtained by level or transit where lines had more than 2 or 3 feet (0.6 or 0.9 m) of relief.

A3.1.3 Data Reduction

The travel times for compressional waves from the shots to the geophones were obtained from the seismograms by visual inspection. These times were plotted at their respective horizontal distances and best-fit lines were drawn through the points to obtain apparent velocities for materials below the seismic line.

A combination of delay time and ray tracing methods was used in a computer program to obtain depth to refracting horizons from the time-distance information.

A3.2 ELECTRICAL RESISTIVITY SURVEYS

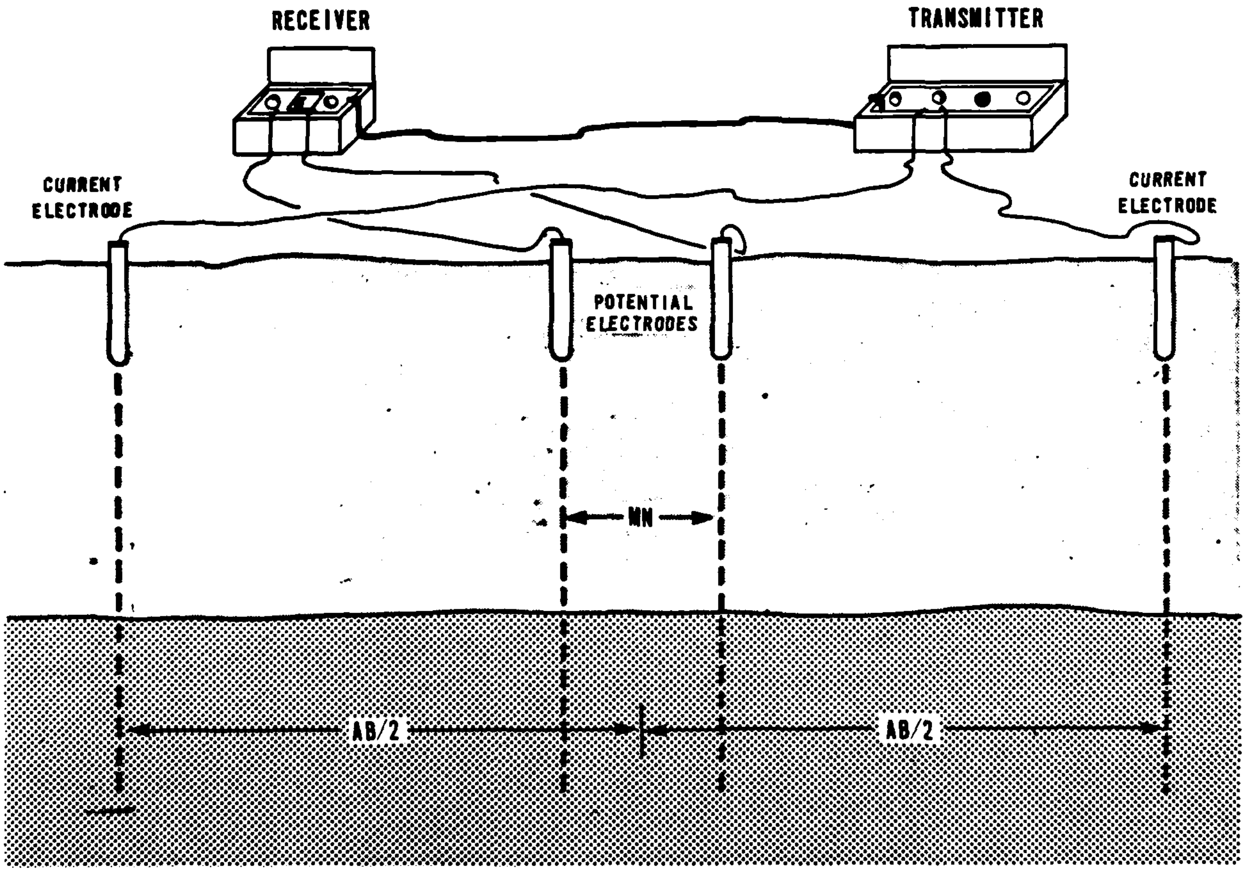
A3.2.1 Instruments

Electrical resistivity measurements were made with a Bison Instrument model 2350B resistivity meter which provides current to the earth through two electrodes and measures the potential (voltage) drop across two other electrodes.

A3.2.2 Field Procedures

Electrical resistivity soundings were made using the Schlumberger electrode arrangement. Soundings are made by successive resistivity measurements which obtain information from deeper and deeper materials. The depth of penetration of the electrical current is increased by increasing the distance between the current electrodes. The arrangement of electrodes in the Schlumberger method is shown in Figure A3-2. The four electrodes are in a line with the two current electrodes on the ends. The distance between the current electrodes (AB) is always five or more times greater than the distance between the potential electrodes (MN).

The initial readings are made with MN equal to 5 feet (1.5 m) and AB equal to 30 feet (9 m). Successive readings were made with AB at 40, 50, 60, 80, 100, 160, 200, 300, 400, 500, and 600 feet (12, 15, 18, 24, 30, 37, 49, 61, 91, 122, 152, and 183 m). MN spacing is sometimes increased one or two times as AB is expanded. This increase is required when the signal drops to a level below the meter's sensitivity. The potential drop is greater between more widely spaced electrodes (MN), so



SCHLUMBERGER ARRAY
ELECTRICAL RESISTIVITY SOUNDINGS
OPERATIONAL BASE SITE
BERYL, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

FIGURE A3-2

FUGRO NATIONAL, INC.

increasing MN increases the signal. When it becomes necessary to increase MN, the spacing of AB is reduced to the spacing of the previous reading. MN is then increased and a measurement is made. This provides two resistivity measurements at the same AB spacing but with different MN spacings.

A3.2.3 Data Reduction

Each apparent resistivity value is plotted versus one-half the current electrode spacing (AB/2) used to obtain it. Log-log graph paper is used to form the coordinates for the graph. A smooth curve is drawn through the points. This sounding curve forms the basis for interpreting the resistivity layering at the sounding location.

A computer program that does iterative "curve-matching" is used to develop a layer model that has a theoretical resistivity curve that is similar to the field curve. Input to the program is generated by digitizing the field curve with an electronic digitizer.

A4.0 ENGINEERING PROCEDURES

Soil engineering activities consisted of the following:

- o Field activities:
  - Borings;
  - Trenches;
  - Test Pits; and
  - Cone Penetrometer Tests;
- o Office activities:
  - Laboratory Tests; and
  - Data Analyses.

The procedures used in the various activities are described in the following sections.

A4.1 BORINGS

A4.1.1 Drilling Techniques

The borings were drilled at designated locations using a truck-mounted Failing 1500 drilling rig with hydraulic pulldown and rotary wash techniques. Borings were nominally 4-7/8 inches (124 mm) in diameter and drilling fluid (typically a bentonite-water slurry) was used to stabilize the hole. A tricone drill bit was used for coarse-grained soils and a drag bit for drilling in fine-grained soils. Nominal maximum depth drilled was 160 feet (49 m). Where rock was encountered in a boring, a minimum of 15 feet (4.6 m) of rock was cored before terminating the boring.

A4.1.2 Method of Sampling

A4.1.2.1 Sampling Intervals

Soil samples were obtained at the following nominal depths as well as at depths of change in soil type.

0' to 2'	(0-0.6 m)	- Drive sample
2.5' to 5'	(0.8 - 1.5 m)	- Pitcher or drive

6' to 8'	(1.8 - 2.4 m)	- Pitcher or drive
10' to 50'	(3.0 - 15.2 m)	- Pitcher or drive - samples at 5' (1.5 m) intervals, starting at a depth of 10' (3.0 m)
50' to 100'	(15.2 - 30.5 m)	- Pitcher or drive - samples at 10' (3.0 m) intervals
100' to 160'	(30.5 - 48.0 m)	- Pitcher or drive - samples at 15' (4.6 m) intervals

A4.1.2.2 Sampling Techniques

a. Fugro Drive Samples: Fugro drive samplers were used to obtain relatively undisturbed soil samples. The Fugro drive sampler is a ring-lined barrel sampler with an outside diameter of 3.0 inches (76.2 mm) and inside diameter of 2.50 inches (63.5 mm). It contains 12 individual 1-inch- (25.4-mm) long rings and is attached to a 12-inch- (30-cm) long waste barrel. The sampler was advanced using a downhole hammer weighing 335 pounds (76 kg) with a drop of 18 inches (46 cm).

The number of blows required to advance the sampler for a 6-inch (15-cm) interval was recorded. Samples obtained were retained in the rings, placed in plastic bags with manually twisted top ends, and sealed in plastic sample containers. Each sample was identified with a label indicating job number, boring number, sample number, depth range, Unified Soil Classification Symbol (USCS), and date. Ring samples were placed in foam-lined steel boxes.

b. Pitcher Samples: The Pitcher sampler was used to obtain undisturbed soil samples. The primary components of this

sampler are an outer rotating core barrel with a bit and an inner, stationary, spring-loaded, thin-wall sampling tube which leads or trails the outer barrel drilling bit depending on the hardness of the material penetrated. The average inside diameter of the sampling tubes used was 2.87 inches (73 mm). Before placing the Pitcher tube in the outer barrel, the tube was inspected for sharpness and protrusions.

The Pitcher sampler was then lowered to the bottom of the boring and the thin-walled sampling tube advanced into the soil ahead of the rotating cutting bit by the weight of the drill rods and hydraulic pulldown. The thin-walled sampling tube was retracted into the core barrel, and the sampler was brought to the surface. After removal of the sampling tube from the core barrel, the length of the recovered soil sample was measured and recorded. Before preparing and sealing the tube, the drilling fluid in the Pitcher tube was removed. Cap plugs were taped in place on the top and bottom of the Pitcher tube and sealed with wax. When Pitcher samples could not be retrieved without disturbance, they were clearly marked as "disturbed." Each sealed Pitcher tube was labeled as explained under "Fugro Drive Samples" and then placed vertically in foam-lined wooden boxes.

c. Wash Samples: Wash samples (cuttings) were obtained by screening the returning drilling fluid during the drilling operations to obtain lithologic information between samples. Recovered wash samples were placed in plastic bags and labeled as explained previously.

d. <u>Split-Spoon Samples</u>: Split-spoon samplers were used to obtain disturbed, but representative, soil samples. The split-spoon sampler consists of a barrel shoe, a split barrel or tube, a solid sleeve, and a sampler head. The inside diameter of the sampler shoe is 1.375 inches (35 mm) and the length is about 18 inches (45.7 cm). Sampling with the split barrel sampler is accomplished by driving the sampler into the ground with a 140-pound (63.6-kg) hammer dropped 30 inches (76 cm). The number of blows required to drive the sampler a distance of 12 inches (30.4 cm) was recorded as the Standard Penetration Resistance (N value). The disturbed samples obtained from the split-spoon sampler were placed in plastic bags and labeled as explained previously.

A4.1.3 <u>Logging</u>

All soils were classified in the field by the procedures outlined in Section A4.4, "Field Visual Soil Classification," of this Appendix. The following general information was entered on the boring logs at the time of drilling: boring number; project name, number, and location; name of drilling company and driller; name of logger and date logged; method of drilling and sampling, drill bit type and size; driving weight; and average drop as applicable. As drilling progressed, the soil samples recovered were visually classified as outlined in Section A4.4, "Field Visual Soil Classification," and the description was entered on the logs. Section A4.4 also discusses other pertinent data and observations made, which were entered on the boring logs during drilling.

A4.1.4 Sample Storage and Transportation

Samples were handled with care, drive-spoon sample containers being placed in foam-lined steel boxes, while Pitcher samples were transported in foam-lined wooden boxes. Particular care was exercised by drivers while traversing rough terrain so as not to cause any disturbance to the undisturbed samples. Whenever ambient air temperatures fell below 32°F, all samples were stored in heated rooms during the field work and transported to Fugro National's Long Beach laboratory in heated cabins in the back of pickup trucks.

A4.1.5 Ground-Water Observation Wells

At designated boring locations, a 2-inch (51-mm) diameter ployvinyl-chloride (PVC) pipe was placed to the bottom of the completed borehole. This PVC pipe slotted in the bottom 20 feet (6 m). The annular space between the PVC pipe and the borehole was backfilled with gravel to a minimum of 30 feet (9 m) above the bottom of the pipe and the pipe was then flushed until clear water came out. The top of the PVC pipe was extended a minimum of 2 feet (0.6 m) above the ground surface and the annular space between the pipe and the borehole (at the ground surface) was covered with impermeable material to prevent the infiltration of surface water. After equilibrium was reached, the water level was measured periodically in the observation wells and recorded.

A4.2 TRENCHES AND TEST PITS

A.4.2.1 Excavation Equipment

The trenches and test pits were excavated using a rubber-tire-mounted Case 580C backhoe with a maximum depth capability of 15 feet (5 m).

A4.2.2 Method of Excavation

Unless caving occurred during the process of excavation, the trench width was nominally 2 feet (0.6 m). Trench depths were typically 14 feet (4.2 m) and lengths ranged from 12 to 20 feet (3.6 to 6.1 m). Test pits were nominally 2 feet (0.6 m) wide, 10 feet (3.0 m) deep, and ranged from 5 to 10 feet (1.5 to 3.0 m) in length. The trench and test pit walls were vertical. However, where surface materials were unstable, the trench walls were sloped back to a safe angle to prevent sloughing during the completion of excavation and logging. The excavated material was deposited on one side at least 4 feet (1.2 m) from the edge of the trenches in order to minimize stress loads at the edges. The excavations were backfilled with the excavated material and the ground surface was restored to a condition as conformable with the surrounding terrain as was practicable.

A4.2.3 Sampling

The following sampling procedures were generally followed for all trenches and test pits.

o Representative bulk soil samples (large or small) were obtained in the top 2 feet (0.6 m). If the soil type changed in the top 2 feet (0.6 m), bulk samples of both soil types were obtained. In addition, bulk samples of all soil types encountered at different depths in the excavation were

obtained. For each soil type in the top 2 to 3 feet (0.6 to 0.9 m), two large bulk samples (weighing about 50 pounds [11.4 kg] each) were taken. Bulk samples from other depths were limited to one bag. When soils from two locations were similar, only a small bag sample weighing about 2 pounds (1 kg) was taken from the second location.

- All large bulk samples were placed first in plastic bags and then in cloth bags. The small bulk samples were placed in small plastic bags. All sample bags of soil were tied tightly at the top to prevent spillage and tagged with the following information: project number; trench or test pit number; bulk sample number; depth range in feet; Unified Soil Classification symbol; and date. The samples were transported to the field office for storage and then to Fugro National's Long Beach office in pickup trucks.

A4.2.4 Logging

The procedures for field visual classification of soil encountered from the trenches and test pits were basically the same as the procedures for logging of borings (Section A4.1.3). For excavations shallower than 4 feet (1.2 m), technicians entered the excavations and logged them. Logging of the excavations deeper than 4 feet (1.2 m) was accomplished from the surface and by observing the backhoe bucket contents. All trench walls were photographed prior to backfilling.

Each field trench and test pit log included trench or test pit number; project name, number, and location; name of excavator; type of excavation equipment; name of logger; and date logged. As excavations proceeded, the soil types encountered were visually classified and described as outlined in Section A4.4, "Field Visual Soil Classification." Section A4.4 also discusses other pertinent data and observations made which were entered on the logs during excavation.

A4.3 CONE PENETROMETER TESTS

A4.3.1 Equipment

The equipment consisted of a truck-mounted (17.5 tons [15,877 kg] gross weight) electronic cone penetrometer equipped with a 15-ton (13,608-kg) friction cone, cone end resistance capacity of 15 tons (13,608 kg) and a 4-1/2-ton (4082-kg) limit on the friction sleeve. All operating controls, recorder, cables, and ancillary equipment were housed in the specially designed vehicle which was completely self-contained. The penetrometer, the key element of the system, contained the necessary load cells and cable connections. One end of the unit was threaded to receive the first sounding rod. When carrying out the tests, hollow rods with an outside diameter of 1.42 inches (3.6 cm) and a length of 3.3 feet (1.0 m) were used to push down the cone.

The hydraulic thrust system was mounted over the center of gravity of the truck permitting use of the full 17.5-ton (15,877-kg) truck weight as load reaction.

The cone had an apex angle of 60° and a base area of 2.3 in^2 (15 cm^2). The resistance to penetration was measured by a built-in load cell in the tip and was relayed to the surface recorder via cables in the sounding rods. The friction sleeve, having an area of 31.0 in^2 (205 cm^2), was fitted above the cone base. The local friction was measured by load cells mounted in the friction sleeve and recorded in the same manner as the end resistance. The end resistance and friction resistance were recorded on a strip chart.

A4.3.2 Test Method

Tests were performed in accordance with ASTM D 3441-75T, "Tentative Method for Deep, Quasi-Static, Cone and Friction-Cone Penetration Tests of Soil." Basically, the test was conducted by positioning the electronic cone penetrometer truck over the designated area for testing, setting the outriggers on the ground surface, checking the level of the rig, then pushing the cone into the ground at a rate of 0.79 inch/sec (2 cm/sec) until refusal (defined as the capacity of the cone, friction sleeve, or hydraulics system) or the desired depth of penetration was reached.

A4.4 FIELD VISUAL SOIL CLASSIFICATION

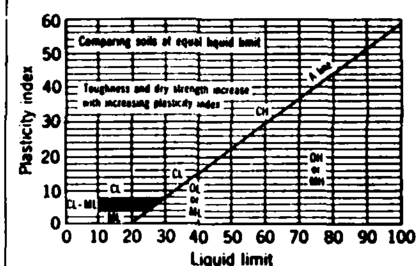
A4.4.1 General

All field logging of soils was performed in accordance with the procedures outlined in this section. Soil samples were visually classified in the field in general accordance with the procedures of ASTM D 2488-69, Description of Soils (Visual-Manual Procedure). The ASTM procedure is based on the Unified Soil Classification System (Table A4-1). It describes several visual and/or manual methods which can be used in the field to estimate the USCS soil group for each sample. The following section details several of the guidelines used in the field for describing soils, drilling and excavating conditions, and unusual conditions encountered.

A4.4.2 Soil Description

Soil descriptions entered on the logs of borings, trenches, and test pits generally included those listed that follow.

Major Divisions			Field Identification Procedures (Excluding particles larger than 3 in. and basing fractions on estimated weights)			Group Symbols[a]	Typical Names	Information Required for Describing Soils	Laboratory Classification Criteria
Coarse-grained soils. More than half of material is *larger* than No. 200 sieve size[b] (The No. 200 sieve size is about the smallest particle visible to naked eye)	Gravels. More than half of coarse fraction is larger than No. 4 sieve size (For visual classification, the ¼ in. size may be used as equivalent to the No. 4 sieve size)	Clean gravels (little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes			*GW*	Well graded gravels, gravel-sand mixtures, little or no fines	Give typical name; indicate approximate percentages of sand and gravel; maximum size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbols in parentheses	Use grain size curve in identifying the fractions as given under field identification. Determine percentages of gravel and sand from grain size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse grained soils are classified as follows: Less than 5% *GW, GP, SW, SP*; More than 12% *GM, GC, SM, SC*; 5% to 12% *Borderline* cases requiring use of dual symbols. $C_U = \frac{D_{60}}{D_{10}}$ Greater than 4; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			Predominantly one size or a range of sizes with some intermediate sizes missing			*GP*	Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for *GW*
		Gravels with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures see *ML* below)			*GM*	Silty gravels, poorly graded gravel-sand-silt mixtures		Atterberg limits below "A" line, or *PI* less than 4. Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
			Plastic fines (for identification procedures, see *CL* below)			*GC*	Clayey gravels, poorly graded gravel-sand-clay mixtures	For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics	Atterberg limits above "A" line, with *PI* greater than 7
	Sands. More than half of coarse fraction is smaller than No. 4 sieve size	Clean sands (little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes			*SW*	Well graded sands, gravelly sands, little or no fines	Example: *Silty sand*, gravelly; about 20% hard, angular gravel particles ½-in. maximum size; rounded and subangular sand grains coarse to fine, about 15% non-plastic fines with low dry strength; well compacted and moist in place; alluvial sand; (*SM*)	$C_U = \frac{D_{60}}{D_{10}}$ Greater than 6; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			Predominantly one size or a range of sizes with some intermediate sizes missing			*SP*	Poorly graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for *SW*
		Sands with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures, see *ML* below)			*SM*	Silty sands, poorly graded sand-silt mixtures		Atterberg limits below "A" line or *PI* less than 5. Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
			Plastic fines (for identification procedures, see *CL* below)			*SC*	Clayey sands, poorly graded sand-clay mixtures		Atterberg limits below "A" line with *PI* greater than 7
Fine-grained soils. More than half of material is *smaller* than No. 200 sieve size			Identification Procedures on Fraction Smaller than No. 40 Sieve Size						
			Dry Strength (crushing characteristics)	Dilatancy (reaction to shaking)	Toughness (consistency near plastic limit)				
	Silts and clays liquid limit less than 50		None to slight	Quick to slow	None	*ML*	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	Give typical name; indicate degree and character of plasticity, amount and maximum size of coarse grains; colour in wet condition, odour if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses	
			Medium to high	None to very slow	Medium	*CL*	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays		
			Slight to medium	Slow	Slight	*OL*	Organic silts and organic silt-clays of low plasticity	For undisturbed soils add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions	
	Silts and clays liquid limit greater than 50		Slight to medium	Slow to none	Slight to medium	*MH*	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts		
			High to very high	None	High	*CH*	Inorganic clays of high plasticity, fat clays	Example: *Clayey silt*, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (*ML*)	
			Medium to high	None to very slow	Slight to medium	*OH*	Organic clays of medium to high plasticity		
Highly Organic Soils			Readily identified by colour, odour, spongy feel and frequently by fibrous texture			*Pt*	Peat and other highly organic soils		



Plasticity chart
for laboratory classification of fine grained soils

From Wagner, 1957.

[a] *Boundary classifications.* Soils possessing characteristics of two groups are designated by combinations of group symbols. For example *GW–GC*, well graded gravel-sand mixture with clay binder.

[b] All sieve sizes on this chart are U.S. standard.

Field Identification Procedure for Fine Grained Soils or Fractions

These procedures are to be performed on the minus No. 40 sieve size particles, approximately 1/64 in. For field classification purposes, screening is not intended, simply remove by hand the coarse particles that interfere with the tests.

Dilatancy (Reaction to shaking):

After removing particles larger than No. 40 sieve size, prepare a pat of moist soil with a volume of about one-half cubic inch. Add enough water if necessary to make the soil soft but not sticky.

Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens and finally it cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.

Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

Dry Strength (Crushing characteristics):

After removing particles larger than No. 40 sieve size, mould a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun or air drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity.

High dry strength is characteristic for clays of the CH group. A typical inorganic silt possesses only very slight dry strength. Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour.

Toughness (Consistency near plastic limit):

After removing particles larger than the No. 40 sieve size, a specimen of soil about one-half inch cube in size, is moulded to the consistency of putty. If too dry, water must be added and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about one-eight inch in diameter. The thread is then folded and re-rolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.

After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles.

The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil. Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line.

Highly organic clays have a very weak and spongy feel at the plastic limit.

UNIFIED SOIL CLASSIFICATION SYSTEM
OPERATIONAL BASE SITE
BERYL, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

TABLE A4-1

FUGRO NATIONAL, INC.

Coarse-Grained Soils	Fine-Grained Soils
USCS Name and Symbol	USCS Name and Symbol
Color	Color
Range in Particle Size	Consistency
Gradation (well, poorly)	Moisture Content
Density	Plasticity
Moisture Content	Reaction to HCl
Particle Shape	
Reaction to HCl	

Some additional descriptions or information recorded for both coarse- and fine-grained soils included: degree of cementation, secondary material, cobbles and boulders, and depth of change in soil type.

Following are definitions of some of the terms and criteria used to describe soils and conditions encountered during the investigations.

a. USCS Name and Symbol: This was derived from Table A4-1, the Unified Soil Classification System. The soils were first designated as coarse- or fine-grained.

Coarse-grained soils are those in which more than half (by weight) of the particles are visible to the naked eye. In making this estimate, particles coarser than 3 inches (76 mm) in diameter were excluded. Fine-grained soils are those in which more than half (by weight) of the particles are so fine that they cannot be seen by the naked eye. The distinction between coarse- and fine-grained can also be made by sieve analysis, with the number 200 sieve-(0.074 mm) size particle considered to be the smallest size visible to the naked eye. In some

instances, the field technicians describing the soils used a number 200 sieve to estimate the amount of fine-grained particles. The coarse-grained soils are further divided into sands and gravels by estimating the percentage of the coarse fraction larger than the number 4 sieve (about 1/4 inch or 5 mm). Each coarse-grained soil is then qualified as silty, clayey, poorly graded, or well graded as discussed under plasticity and gradation.

Fine-grained soils were identified in the field as clays or ed, or well graded as discussed under plasticity and gradation.

Fine-grained soils were identified in the field as clays or silts with appropriate adjectives (clayey silt, silty clay, etc.) based on the results of dry strength, dilatancy, and plastic thread tests (see ASTM D 2488-69 for details of these tests).

Dual USCS symbols and adjectives were used to describe soils exhibiting characteristics of more than one USCS group.

b. Color: Color descriptions were recorded using the following terms with abbreviations in parentheses.

White (w)	Green (gn)
Yellow (y)	Blue (bl)
Orange (o)	Gray (gr)
Red (r)	Black (blk)
Brown (br)	

Color combinations as well as modifiers such as light (lt) and dark (dk) were used.

c. Range in Particle Size: For coarse-grained soils (sands and gravels), the size range of the particles visible to the naked eye was estimated as fine, medium, coarse, or a combined range (fine to medium).

d. Gradation: Well-graded indicates a coarse-grained soil which has a wide range in grain size and substantial amounts of most intermediate particle sizes. A coarse-grained soil was identified as poorly graded if it consisted predominantly of one size (uniformly graded) or had a wide range of sizes with some intermediate sizes obviously missing (gap-graded).

e. Density or Consistency: The density or consistency of the in-place soil was estimated based on the number of blows required to advance the Fugro drive or split-spoon sampler, the drilling rate (difficulty) and/or hydraulic pulldown needed to drill, visual observations of the soil in the trench or test pit walls, ease or difficulty of excavation of trench or test pit, or trench or test pit wall stability. For fine-grained soils, the field guides to shear strength presented below were also used to estimate consistency.

o Coarse-grained soils - GW, GP, GM, GC, SW, SP, SM, SC (gravels and sands)

Consistency	N-Value (ASTM D 1586-67), Blows/Foot
Very Loose	0 - 4
Loose	4 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	>50

o Fine-grained soils - ML, MH, CL, CH (silts and clays)

Consistency	Shear Strength (ksf)	Field Guide
Very Soft	<0.25	Sample with height equal to twice the diameter, sags under own weight
Soft	0.25-0.50	Can be squeezed between thumb and forefinger
Firm	0.50-1.00	Can be molded easily with fingers
Stiff	1.00-2.00	Can be imprinted with slight pressure from fingers
Very Stiff	2.00-4.00	Can be imprinted with considerable pressure from fingers

Consistency	Shear Strength (ksf)	Field Guide
Hard	Over 4.00	Cannot be imprinted by fingers

f. Moisture Content: The following guidelines were used in the field for describing the moisture in the soil samples:

Dry : No feel of moisture

Slightly Moist: Much less than normal moisture

Moist : Normal moisture for soil

Very Moist : Much greater than normal moisture

Wet : At or near saturation

g. Particle Shape: Coarse-grained soils

Angular : Particles have sharp edges and relatively plane sides with unpolished surfaces

Subangular: Particles are similar to angular but have somewhat rounded edges

Subrounded: Particles exhibit nearly plane sides but have well-rounded corners and edges

Rounded : Particles have smoothly curved sides and no edges

h. Reaction to HCl: As an aid for identifying cementation, some soil samples were tested in the field for their reaction

to dilute hydrochloric acid. The intensity of the HCl reaction was described as none, weak, or strong.

i. <u>Degree of Cementation</u>: Based on the intensity of the HCl reaction and observation, the degree of cementation of a soil layer was described as weak to strong. Also, the following stages of development of a caliche (cemented) profile were indicated where applicable.

Stage	Gravelly Soils	Nongravelly Soils
I	Thin, discontinuous pebble coatings	Few filaments or faint coatings

Stage	Gravelly Soils	Nongravelly Soils
I	Thin, discontinuous pebble coatings	Few filaments or faint coatings
II	Continuous pebble coatings, some interpebble fillings	Few to abundant nodules, flakes, filaments
III	Many interpebble fillings	Many nodules and internodular fillings
IV	Laminar horizon overlying plugged horizon	Increasing carbonate impregnation

j. <u>Secondary Material</u>: Example - Sand with trace to some silt

Trace	5-12%	(by dry weight)
Little	13-20%	(by dry weight)
Some	>20%	(by dry weight)

k. <u>Cobbles and Boulders</u>: A cobble is a rock fragment, usually rounded or subrounded, with an average diameter between 3 and 12 inches (76 and 305 mm). A boulder is a rock fragment, usually rounded by weathering or abrasion, with an average diameter of 12 inches (305 mm) or more. The presence of cobbles

and/or boulders was identified by noting the sudden change in drilling difficulty, by observing cuttings in borings, or by visual observation in excavations. An estimate of the size, range, and percentage of cobbles and/or boulders in the strata was recorded on the logs.

1. Depth of Change in Soil Type: During drilling of borings, the depths of changes in soil type were determined by observing samples, drilling rates, and changes in color or consistency of drilling fluid, and relating these to depth marks on the drilling rods. In excavations, strata thicknesses were measured with a tape. All soil type interfaces were recorded on the logs by a horizontal line at the approximate depth mark.

In addition to the observations recorded relating to soil descriptions, remarks concerning drilling difficulty, loss of drilling fluid in the boring, water levels encountered, trench wall stability, ease of excavation, and other unusual conditions were recorded on the logs.

A4.5 LABORATORY TESTS

Laboratory tests were performed on selected representative undisturbed and bulk samples. All laboratory tests (except chemical tests) were performed in Fugro National's Long Beach laboratory. The chemical tests were conducted by Pomeroy, Johnson, and Bailey Laboratories of Pasadena, California. All tests were performed in general accordance with the American Society for Testing and Materials (ASTM) procedures. The types

of tests performed and their ASTM designations are summarized as follows.

Type of Test	ASTM Designation
Unit Weight	D 2937-71
Moisture Content	D 2216-71
Particle-Size Analysis	D 422-63
Liquid Limit	D 423-66
Plastic Limit	D 424-59
Triaxial Compression	D 2850-70
Unconfined Compression	D 2166-66
Direct Shear	D 3080-72
Consolidation	D 2435-70
Compaction	D 1557-70
California Bearing Ratio (CBR)	D 1883-73
Specific Gravity	D 854-58
Water Soluble Sodium	D 1428-64
Water Soluble Chloride	D 512-67
Water Soluble Sulfate	D 516-68
Water Soluble Calcium	D 511-72
Calcium Carbonate	D 1126-67
Test for Alkalinity (pH)	D 1067-70

A4.6 DATA REDUCTION

The field logs of all borings, trenches and test pits were prepared by systematically combining the information given on the field logs with the laboratory test results. The resultant logs generally include the following information: description of soil types encountered; sample types and intervals; lithology (graphic soil column); estimates of soil density or consistency; depth locations of changes in soil types; remarks concerning trench wall stability; drilling difficulty, cementation, and cobbles and boulders encountered; and the total depth of exploration. Laboratory test results presented in the logs include dry density and moisture content; percent of gravel, sand, and fines; and liquid limit and plasticity index. Also, miscellaneous information such as surface elevation, surficial geologic

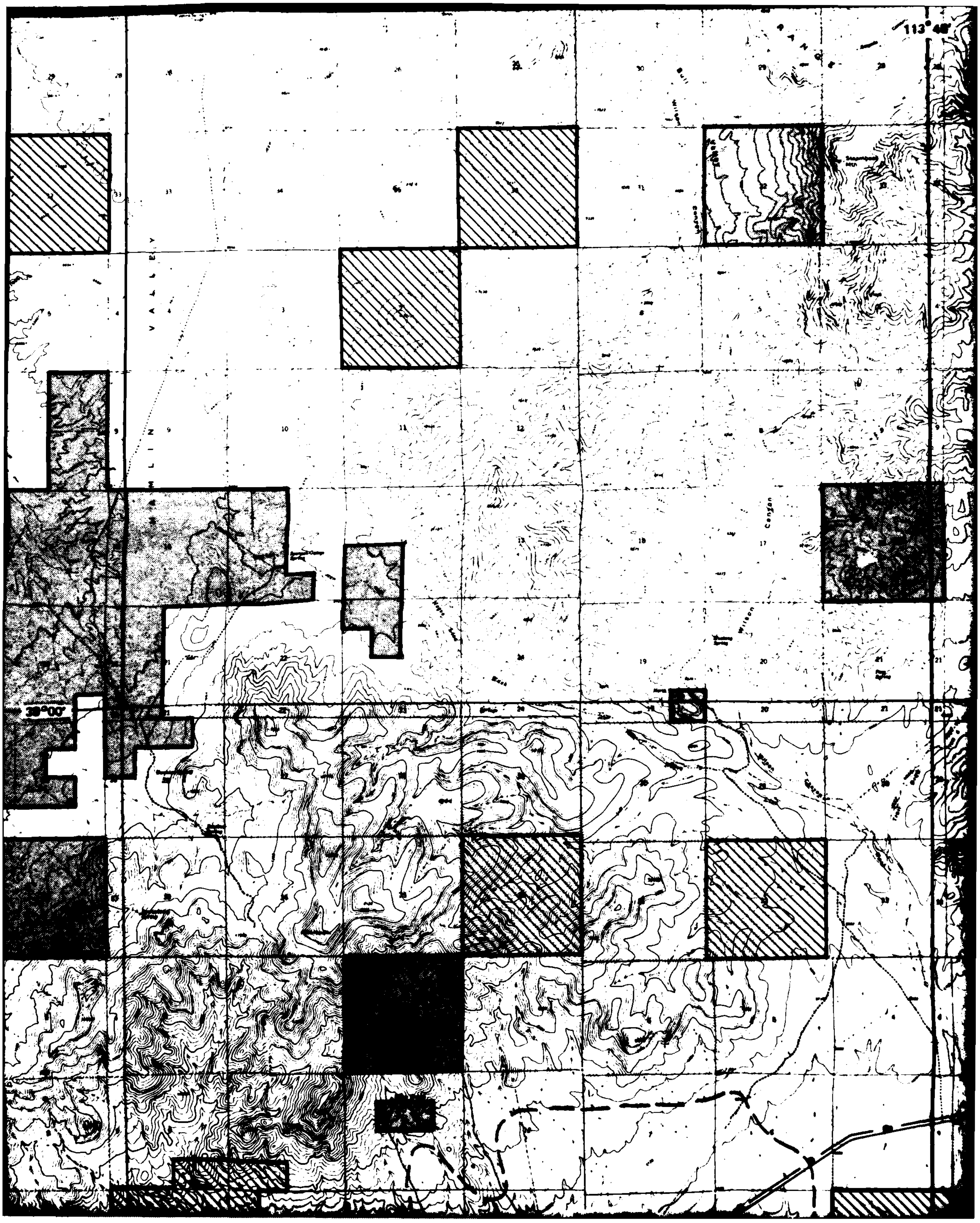
unit, date of activity, equipment used, and dimensions of the activity are shown on the log.

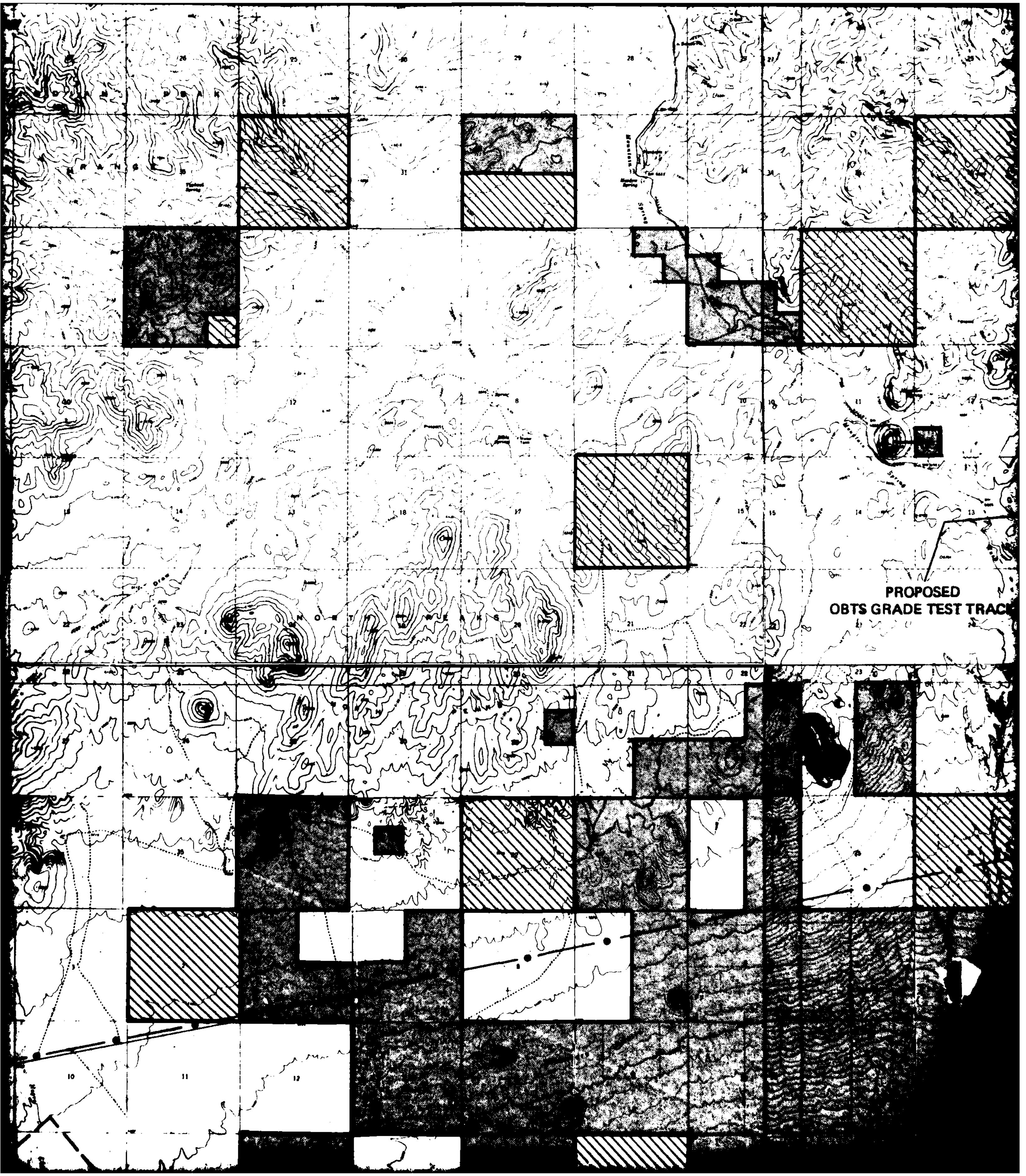
Laboratory data were summarized in tables. All samples which were tested in the laboratory were listed. Results of sieve analyses, hydrometer, Atterberg limits, in-situ dry density and moisture content tests, and calculated degree of saturation and void ratio were entered on the tables. Test summary sheets for triaxial compression, unconfined compression, direct shear, consolidation, chemical, CBR, and compaction tests were prepared separately.

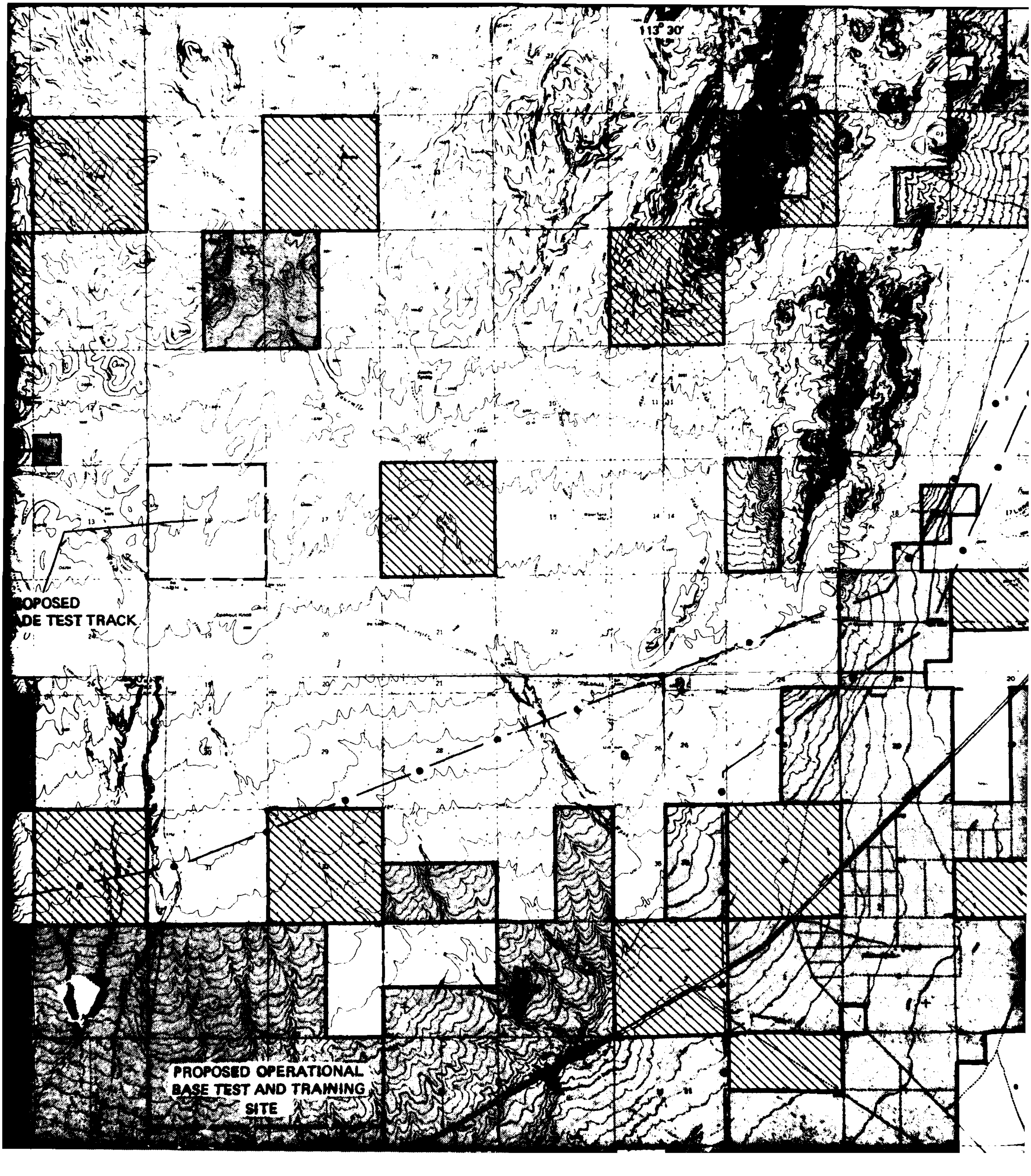
The Cone Penetrometer Test results consist of continuous plots of cone resistance, friction sleeve resistance, and friction ratio versus depth from ground surface. Beside the plot is shown a soil column with USCS soil types encountered at the test location.

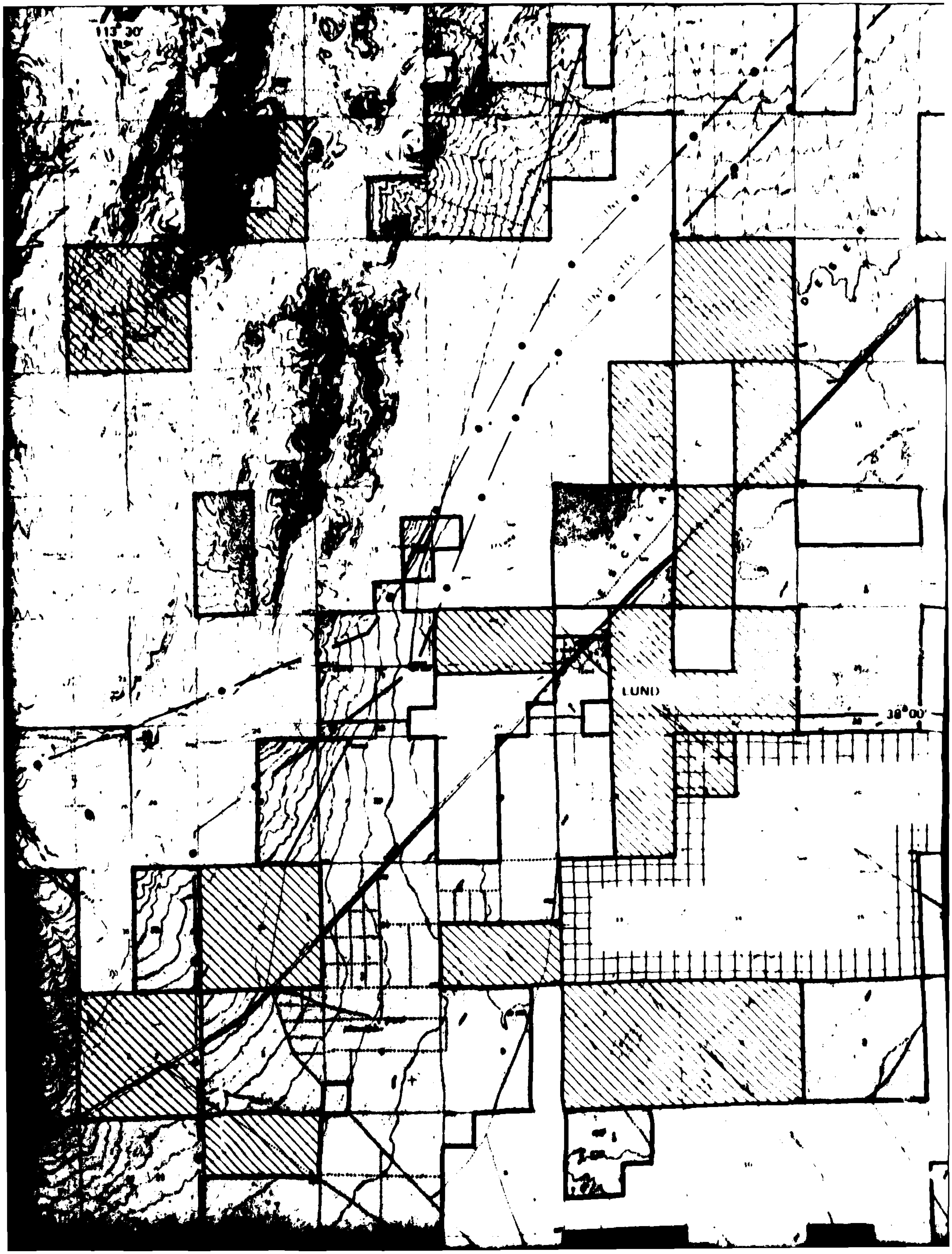
Volume II titled "Geotechnical Data" presents the following finalized basic engineering data.

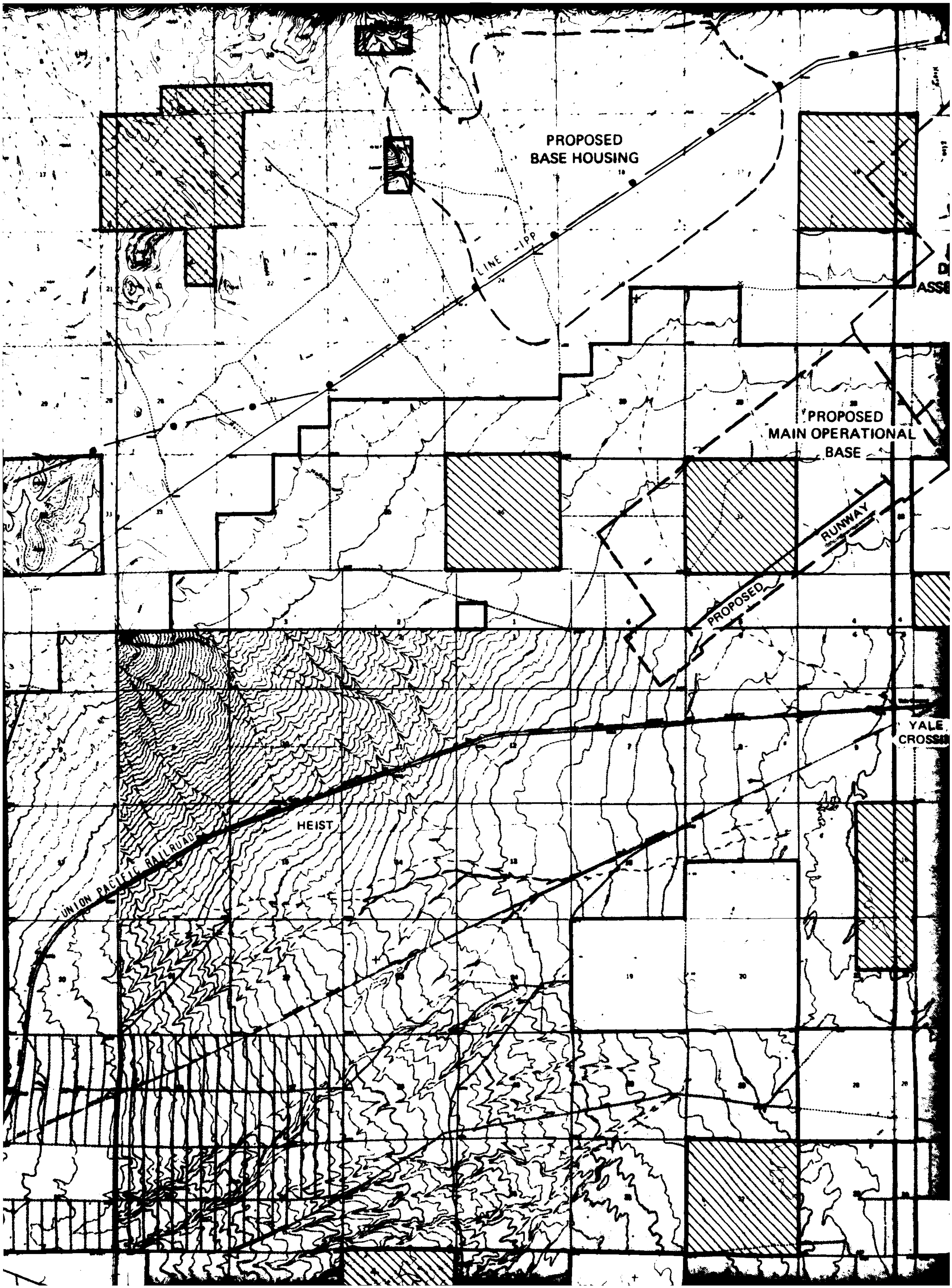
Boring Logs	Section II - 2.0
Trench Logs	Section II - 3.0
Test Pit Logs	Section II - 4.0
Laboratory Test Results	Section II - 5.0
Cone Penetrometer Test Results	Section II - 6.0

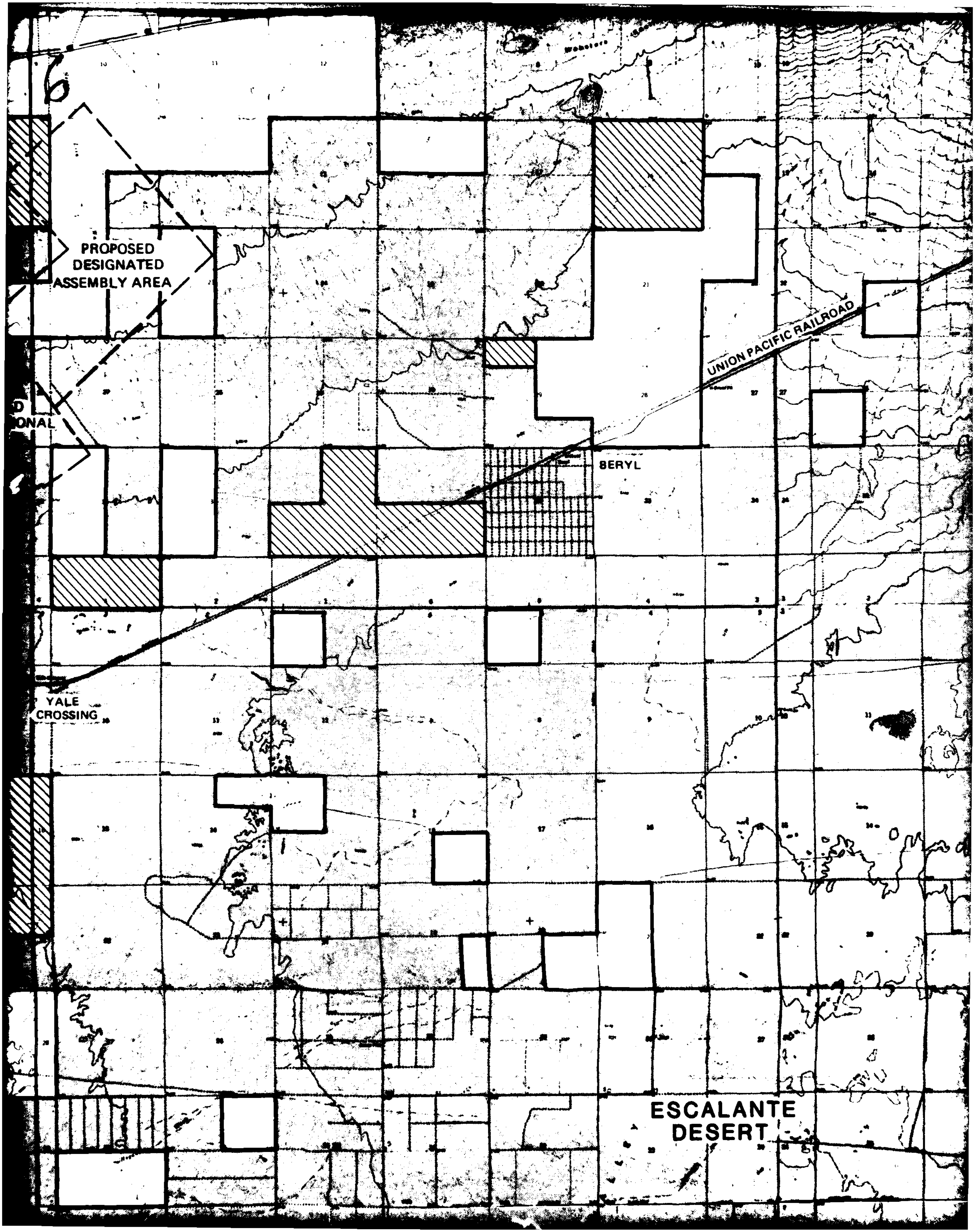

113°46'
38°00'

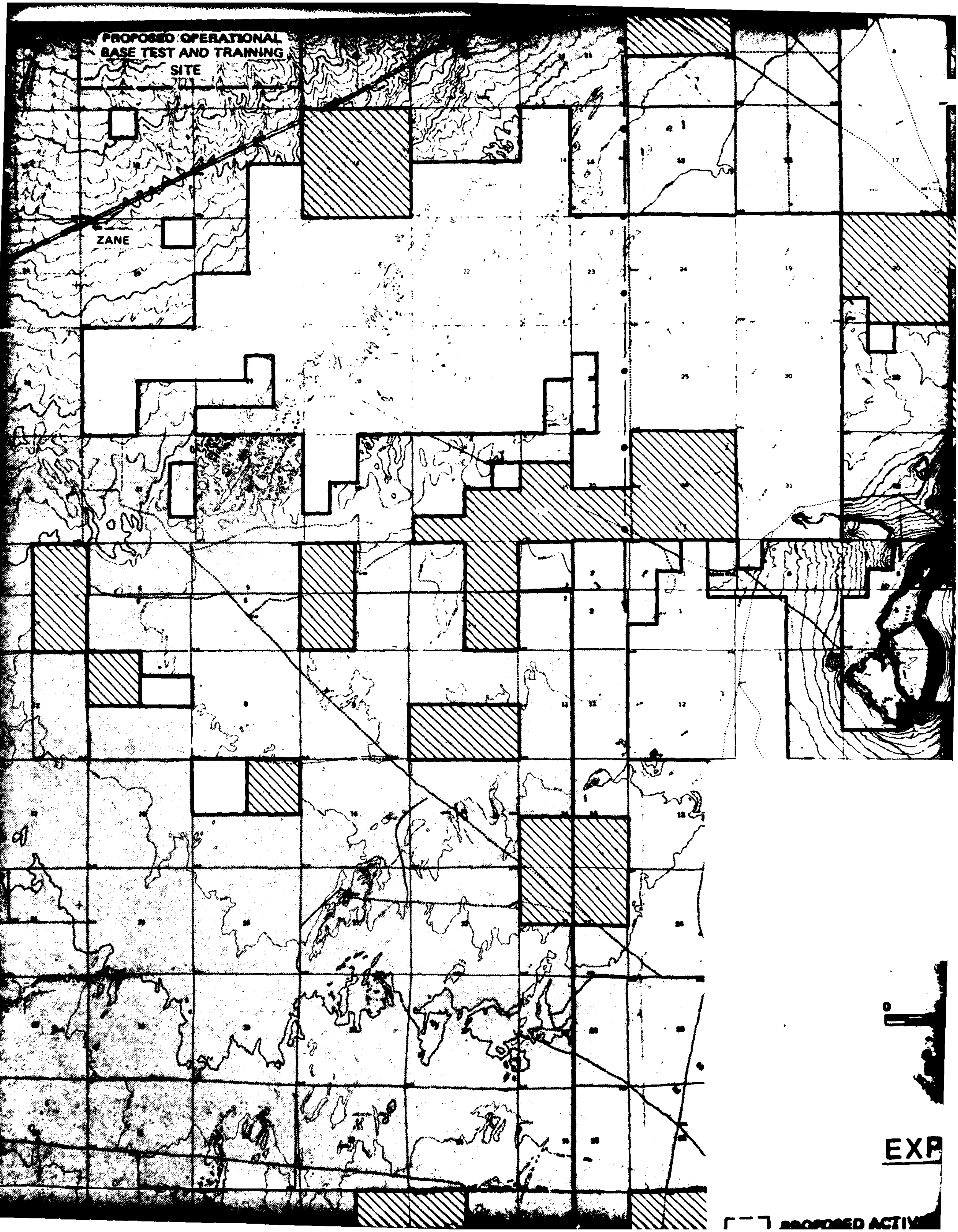

PROPOSED
OBTS GRADE TEST TRACK


113° 30'
OPOSED
ADE TEST TRACK
PROPOSED OPERATIONAL
BASE TEST AND TRAINING
SITE

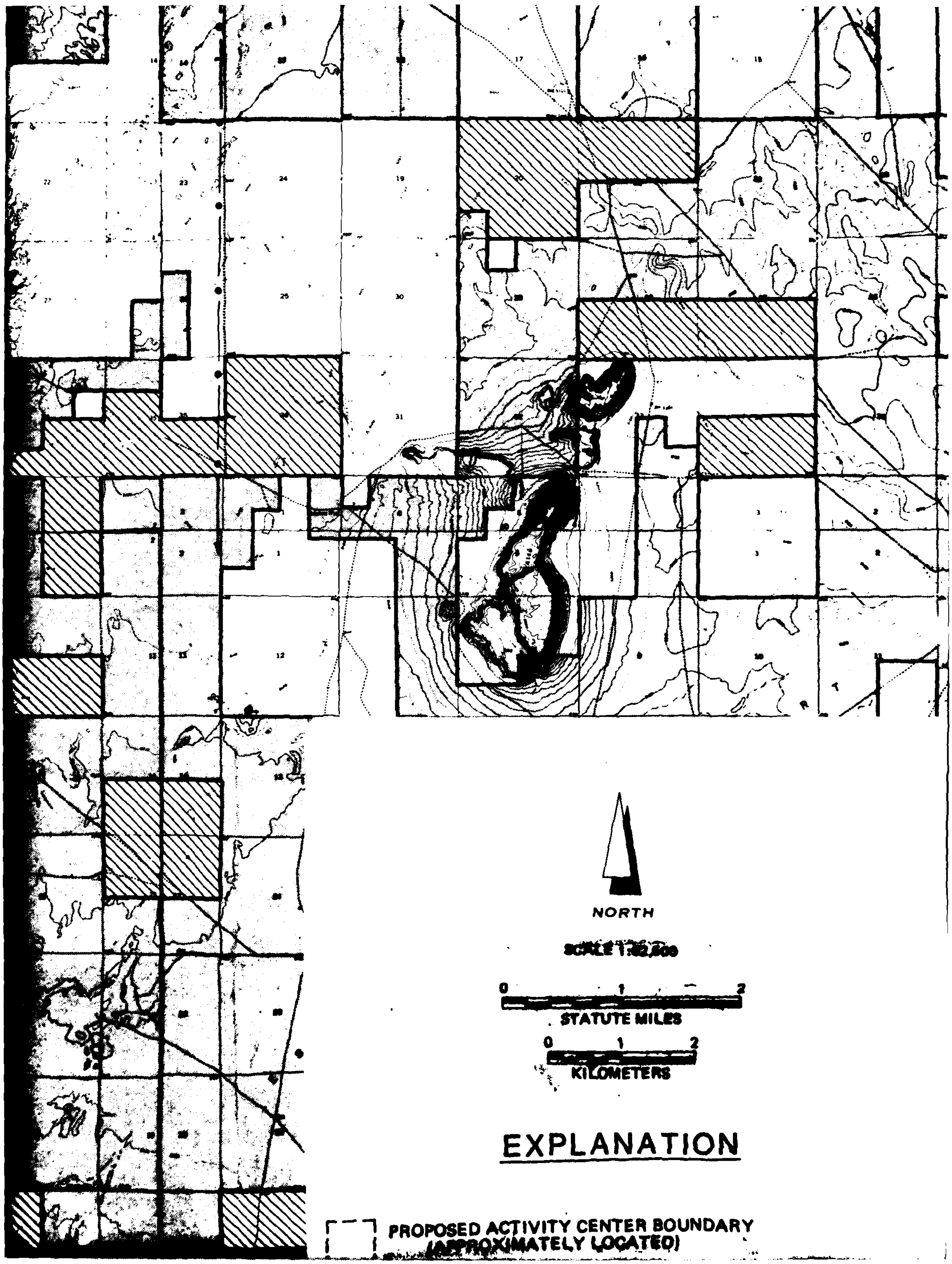

113°30'
LUND
38°00'

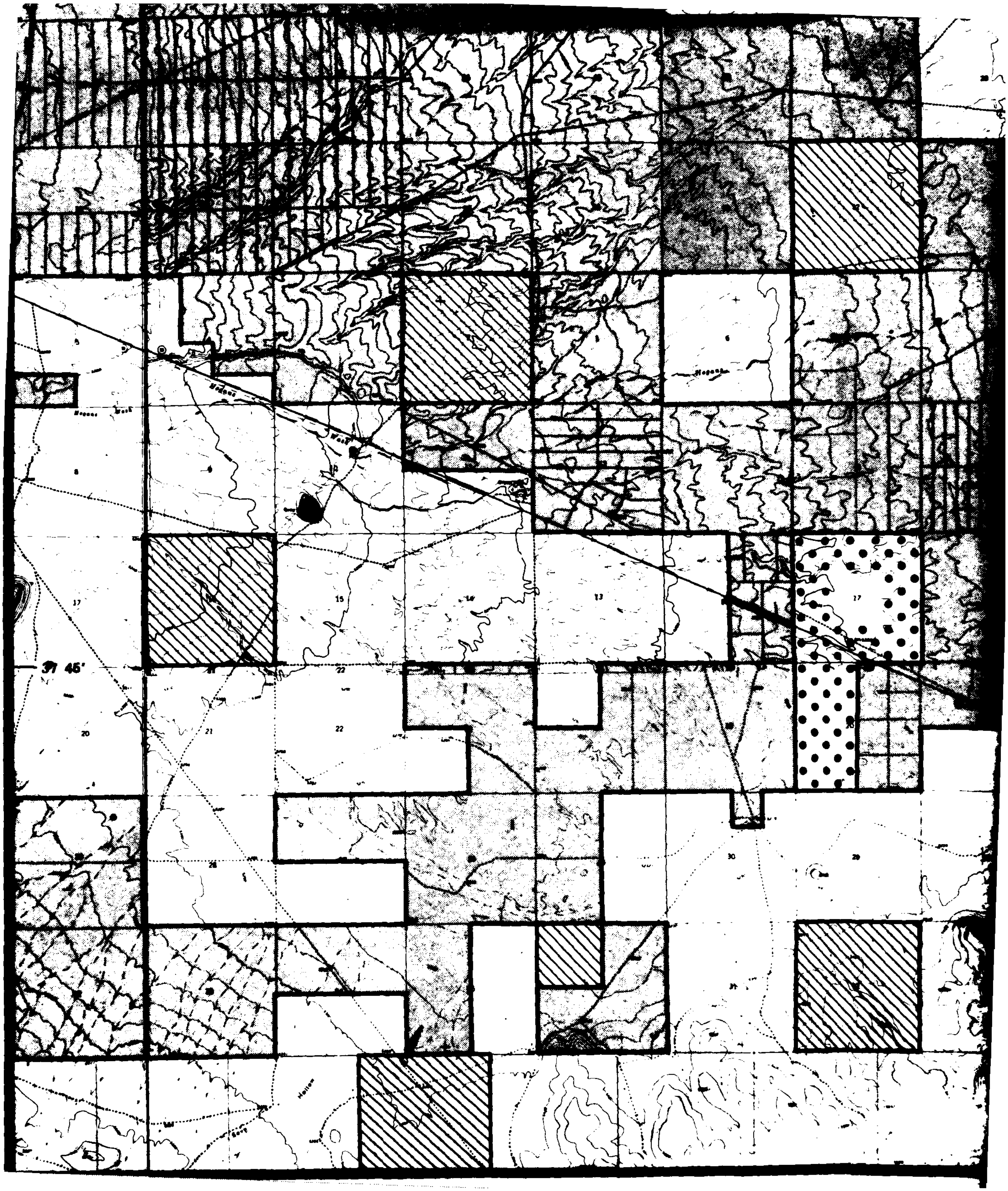

PROPOSED
BASE HOUSING
LINE - IPP
PROPOSED
MAIN OPERATIONAL
BASE
RUNWAY
PROPOSED
YALE
CROSSI
HEIST
UNION PACIFIC RAILROAD

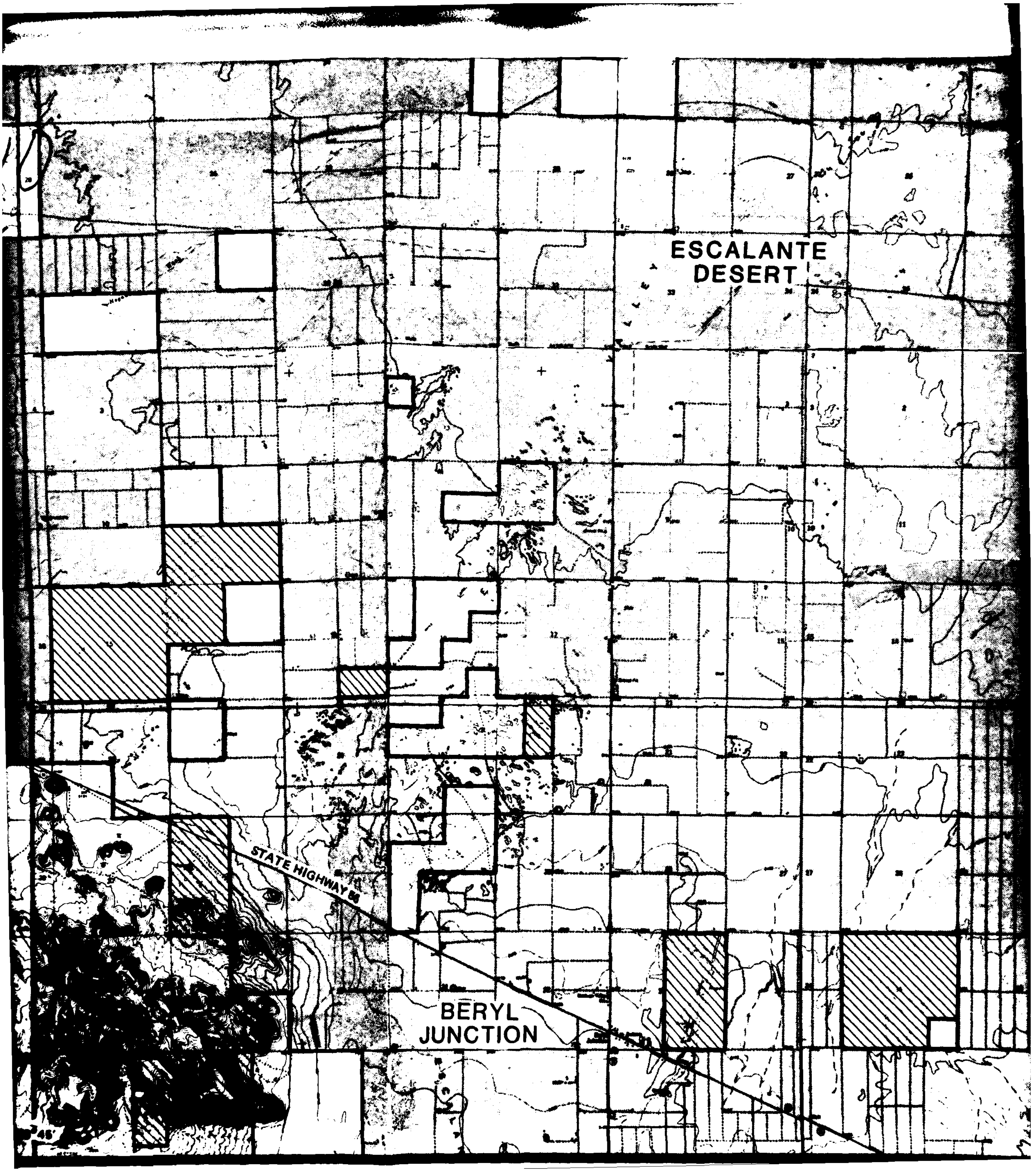

6
PROPOSED
DESIGNATED
ASSEMBLY AREA
UNION PACIFIC RAILROAD
BERYL
YALE
CROSSING
ESCALANTE
DESERT

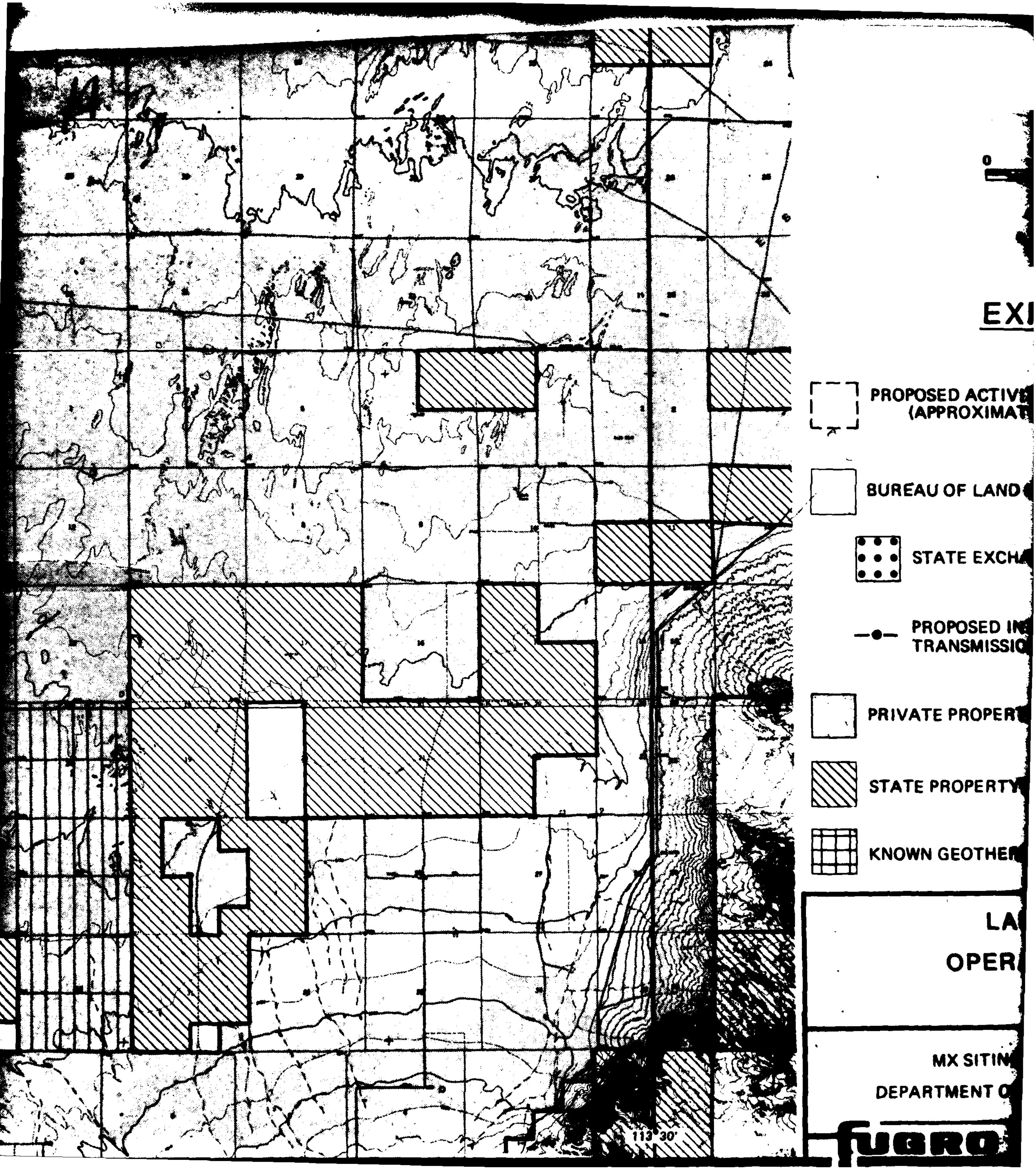


PROPOSED OPERATIONAL BASE TEST AND TRAINING SITE
ZANE
EXP
PROPOSED ACTIV


NORTH
SCALE 1:62,500
0 1 2
STATUTE MILES
0 1 2
KILOMETERS
EXPLANATION
PROPOSED ACTIVITY CENTER BOUNDARY (APPROXIMATELY LOCATED)

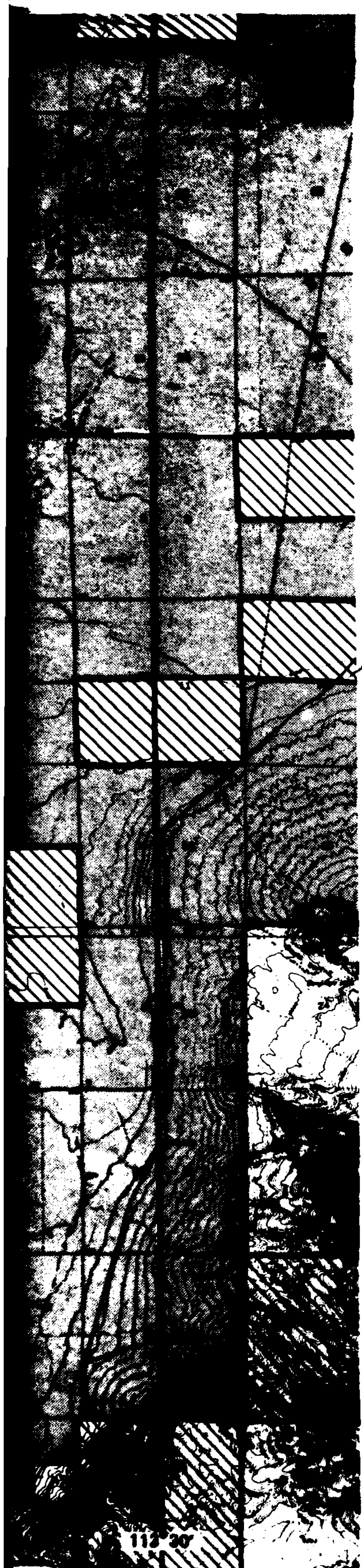



ESCALANTE
DESERT
STATE HIGHWAY 56
BERYL
JUNCTION



PROPOSED
BUREAU OF LAND
STATE
PROPOSED
PRIVATE
STATE PROPERTY
KNOWN
DEPARTMENT
113°30'

12



NORTH

0 1 2
STATUTE MILES

0 1 2
KILOMETERS

EXPLANATION

PROPOSED ACTIVITY CENTER BOUNDARY (APPROXIMATELY LOCATED)

BUREAU OF LAND MANAGEMENT (BLM) LAND

STATE EXCHANGE APPLICATION

PROPOSED INTERMOUNTAIN POWER PROJECT (IPP) TRANSMISSION LINE (500 KV D. C.) ALIGNMENT

PRIVATE PROPERTY INCLUDING MINING PATENTS

STATE PROPERTY INCLUDING MATERIAL SITES

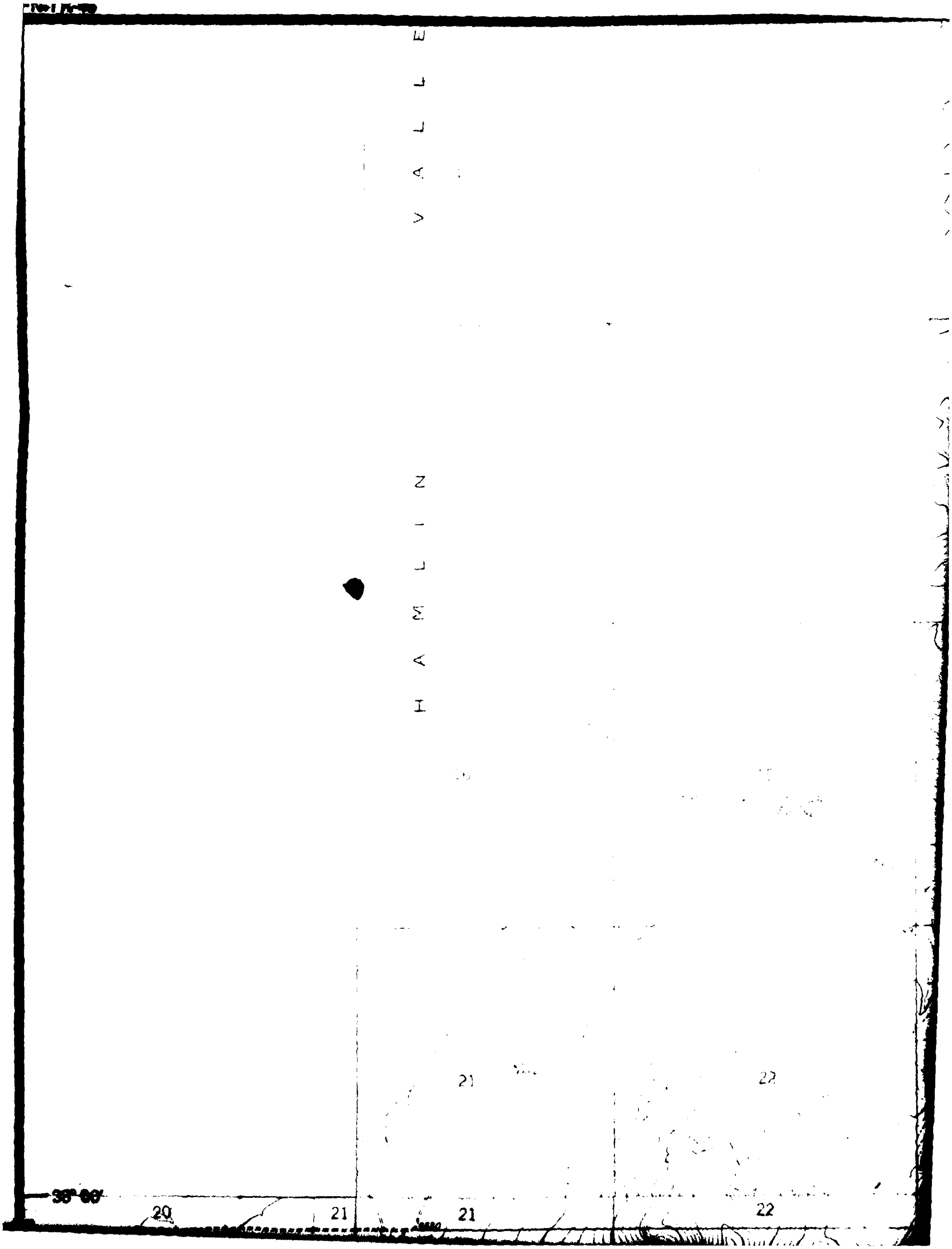
KNOWN GEOTHERMAL RESOURCE AREA

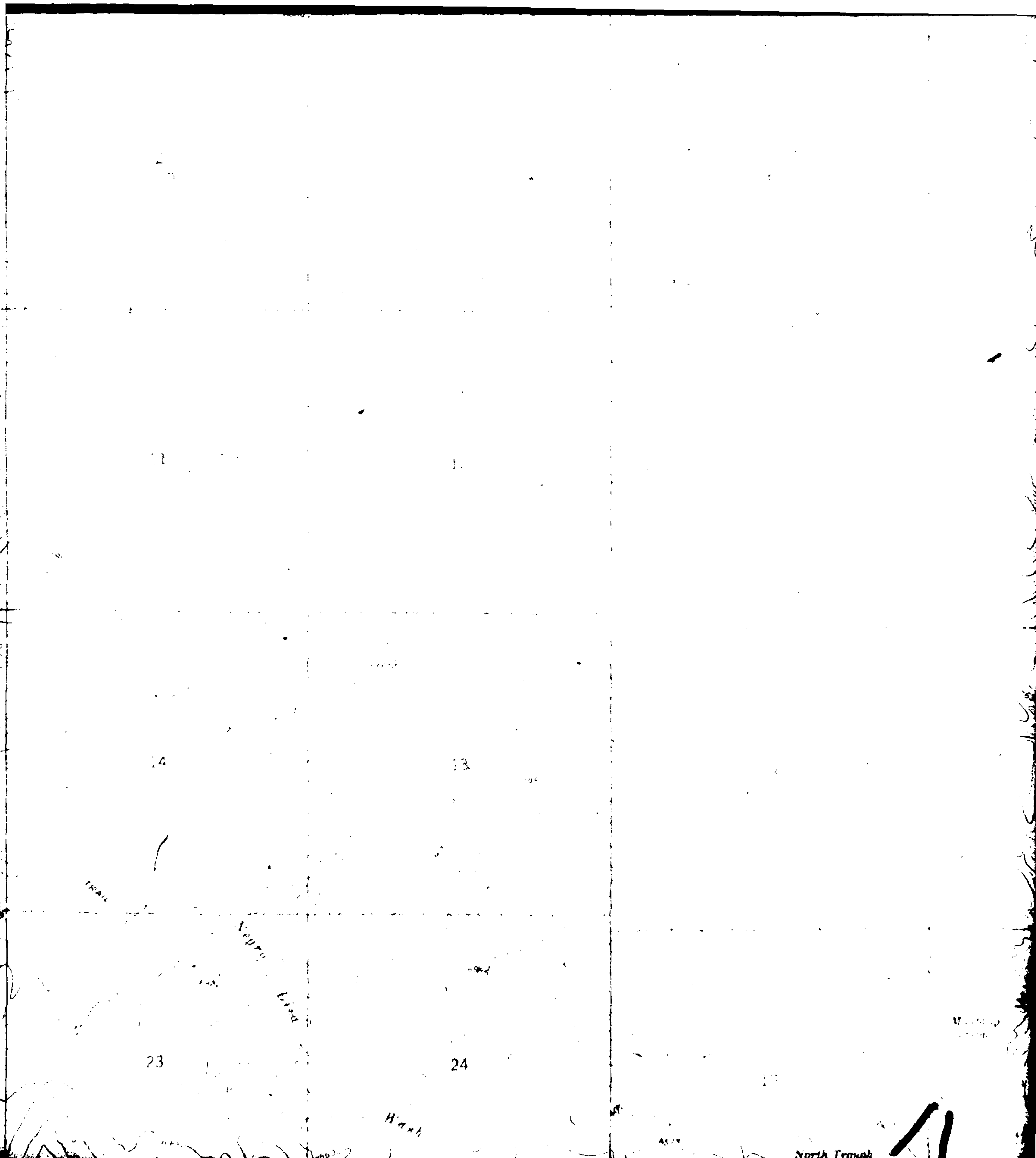
LAND STATUS MAP
OPERATIONAL BASE SITE
BERYL, UTAH

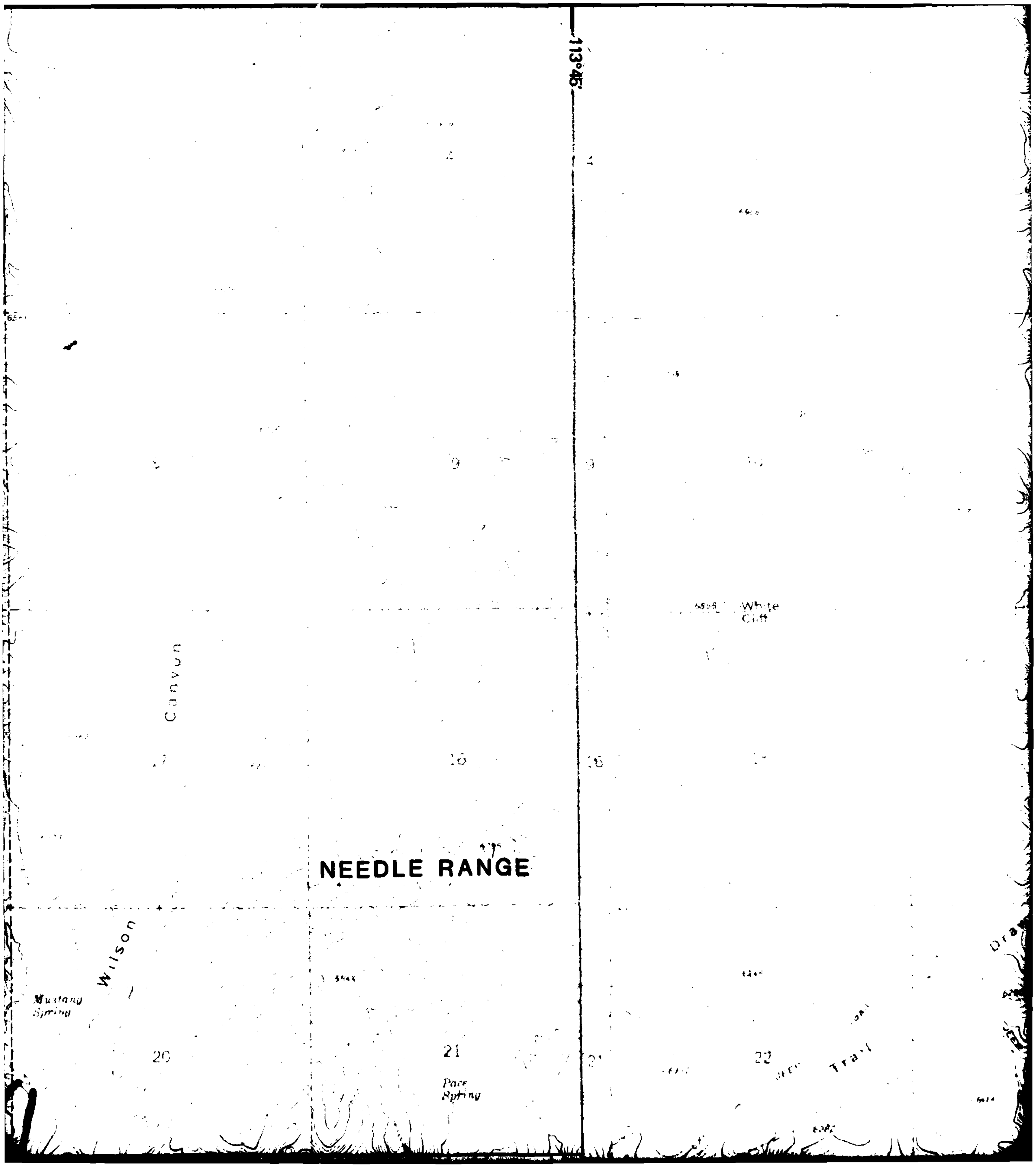
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

DRAWING
4-1

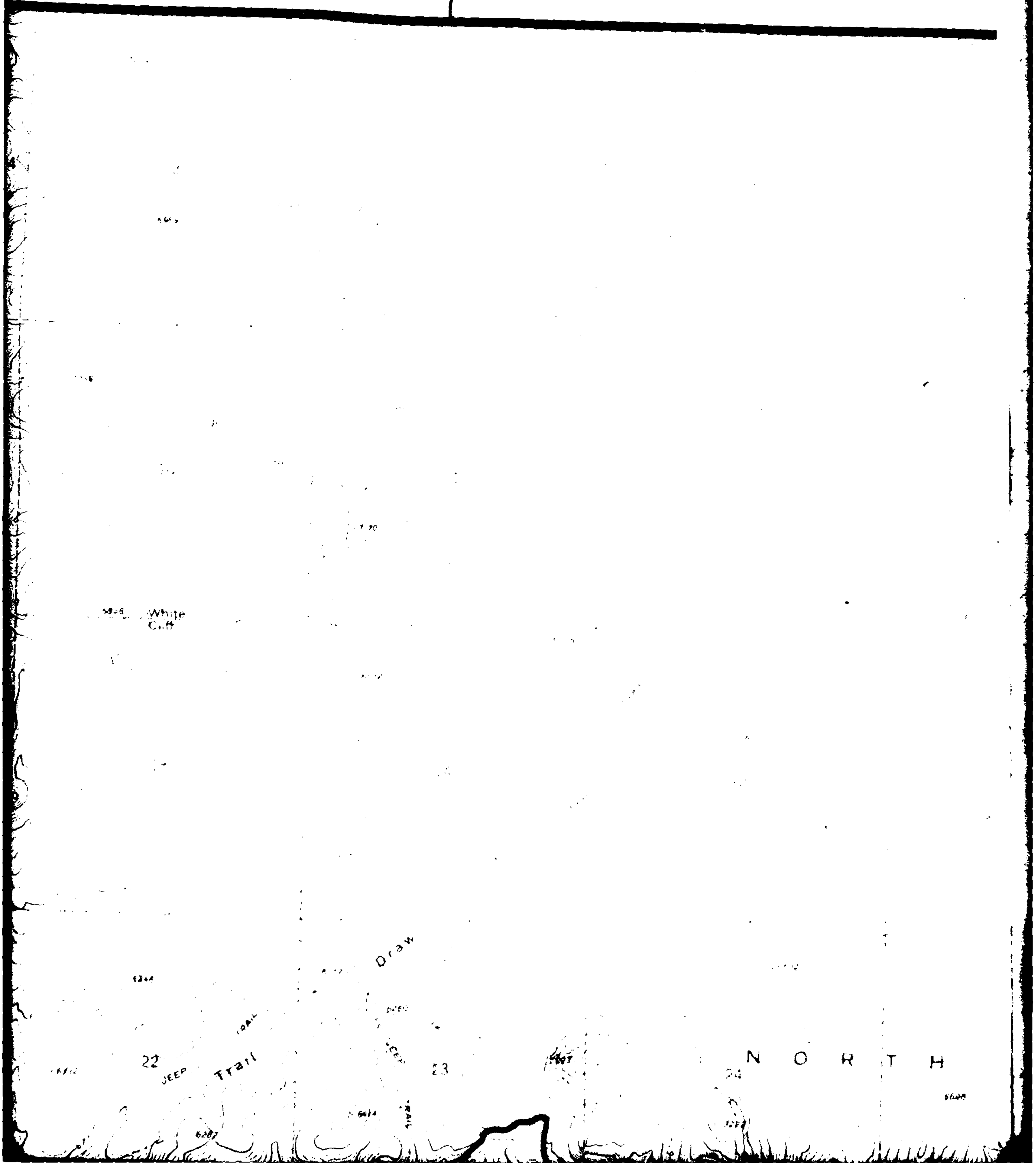
FUGRO NATIONAL, INC.

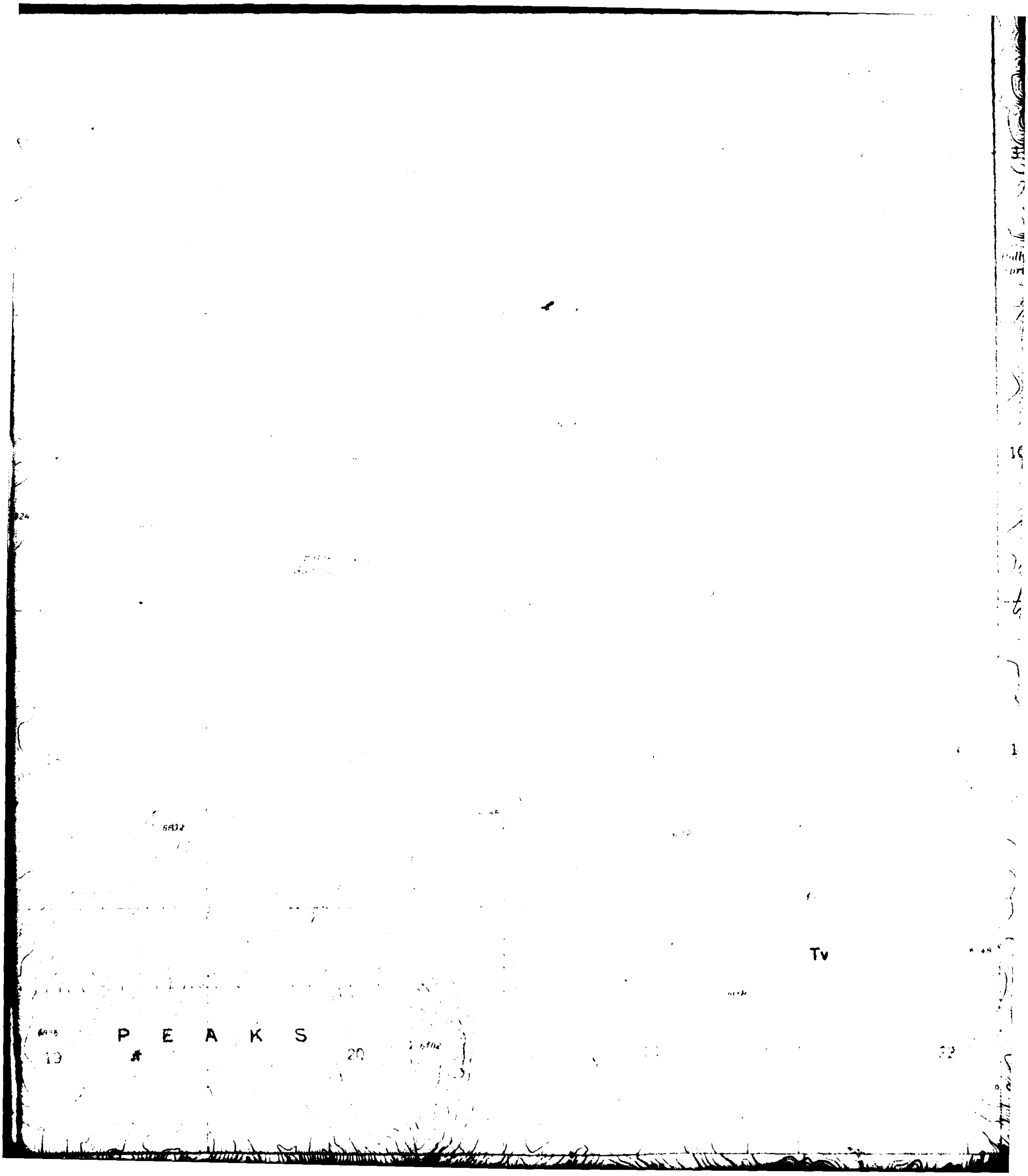

HAMLIN VALLE
36° 00′
20
21
21
21
22
22

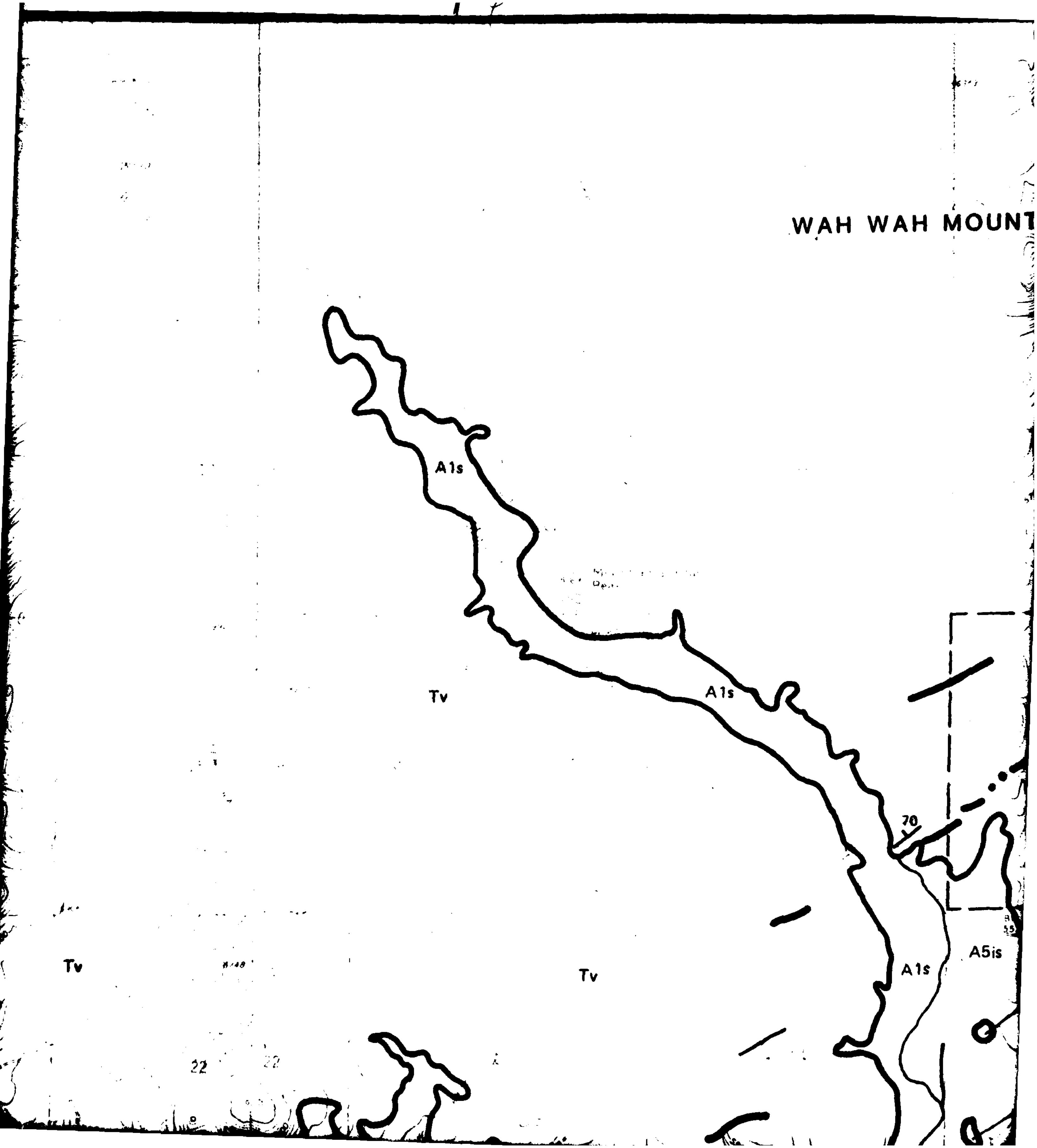

14
TRAIL
23
24
North Trough


113°45'
4
4
9
9
White Cliff
Canyon
16
16
NEEDLE RANGE
Wilson
Mustang Spring
20
21
Pace Spring
22
Trail

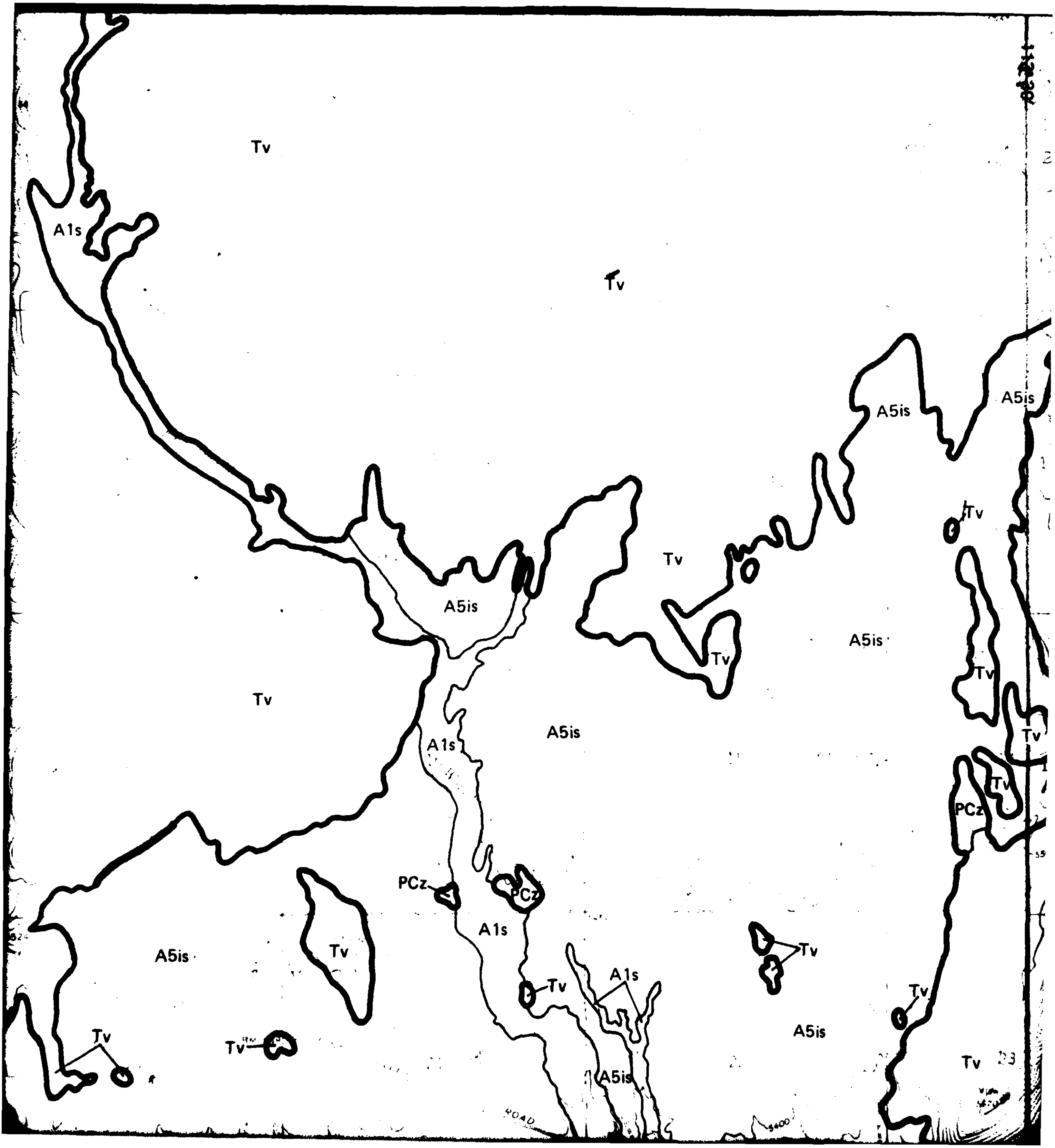
14

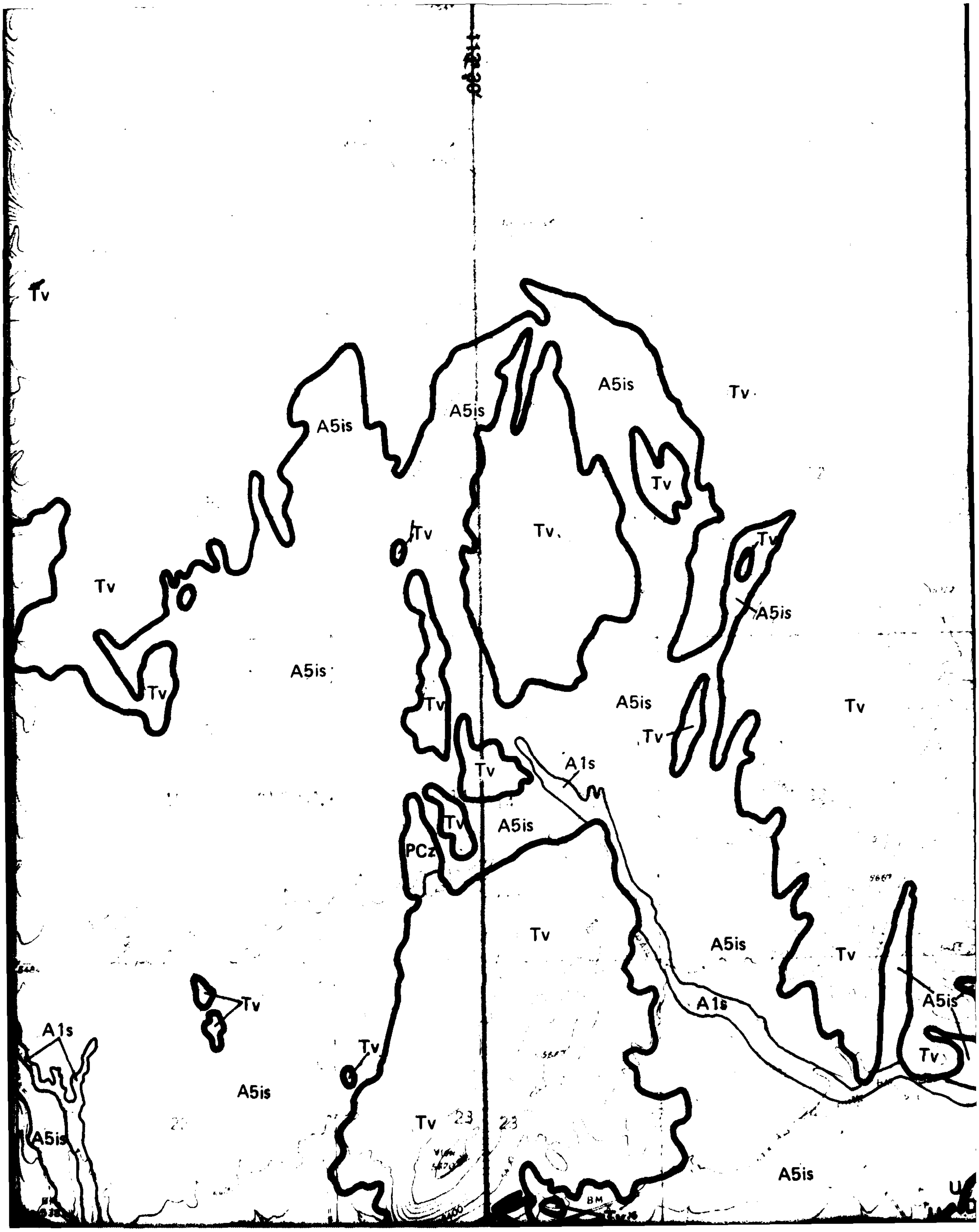



Tv
P E A K S
19
20

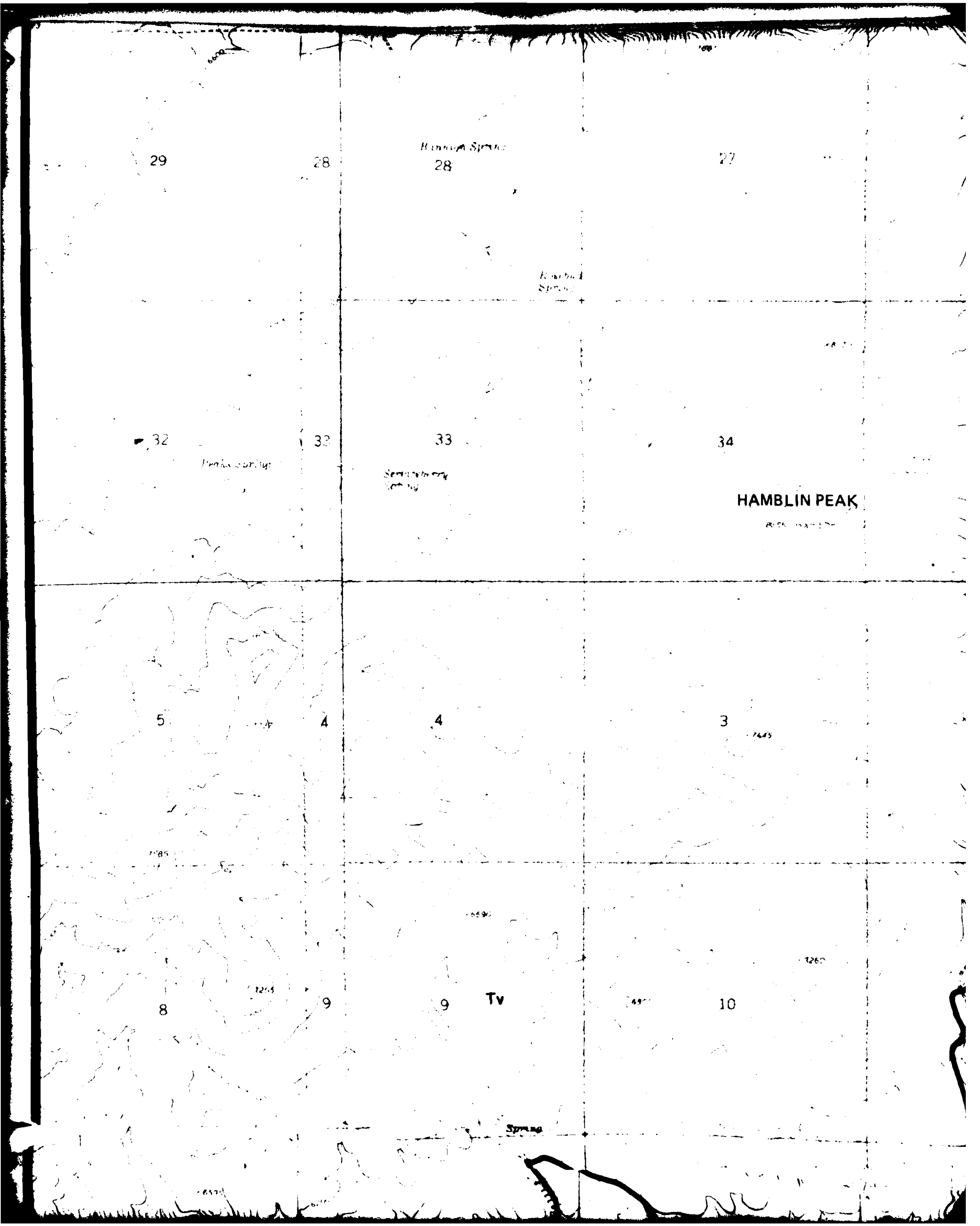


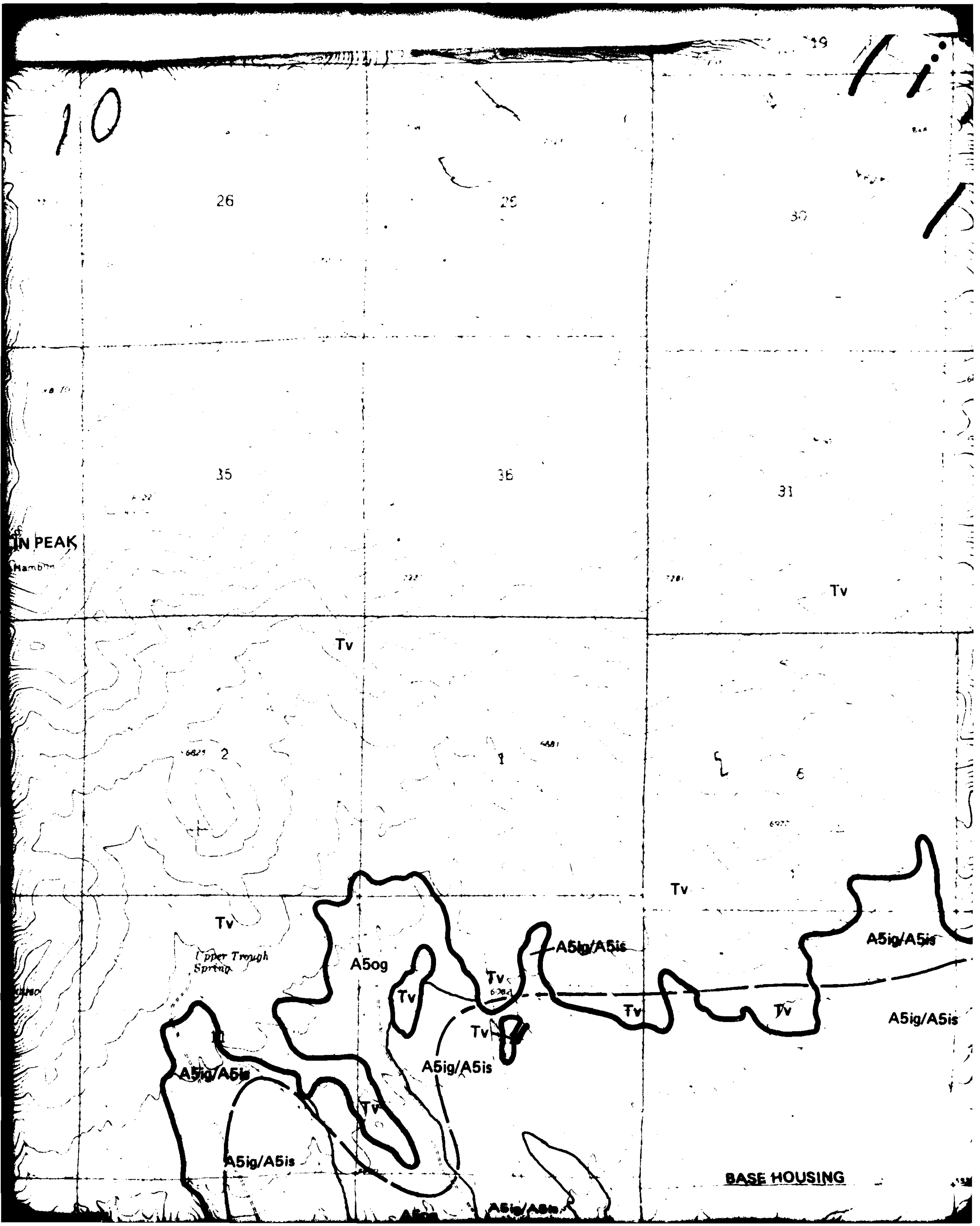
WAH WAH MOUNT
A1s
A1s
Tv
70
A1s
A5is
Tv
Tv
22

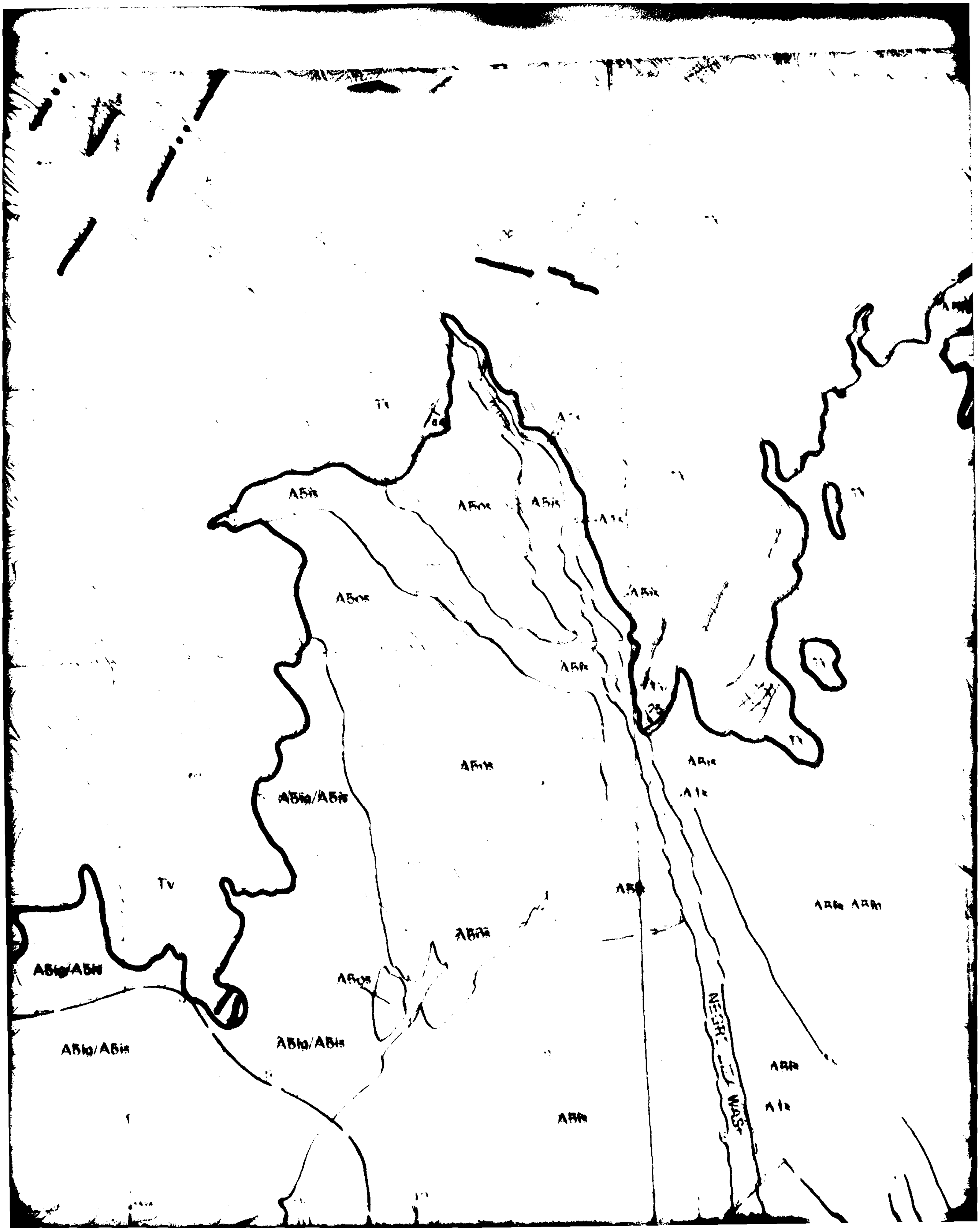

Tv
A1s
Tv
A5is
A5is
Tv
A5is
Tv
Tv
A5is
Tv
A5is
A1s
Tv
Tv
Tv
PCz
PCz
PCz
A1s
A5is
Tv
Tv
A1s
Tv
Tv
Tv
A5is
Tv
Tv
A5is
ROAD

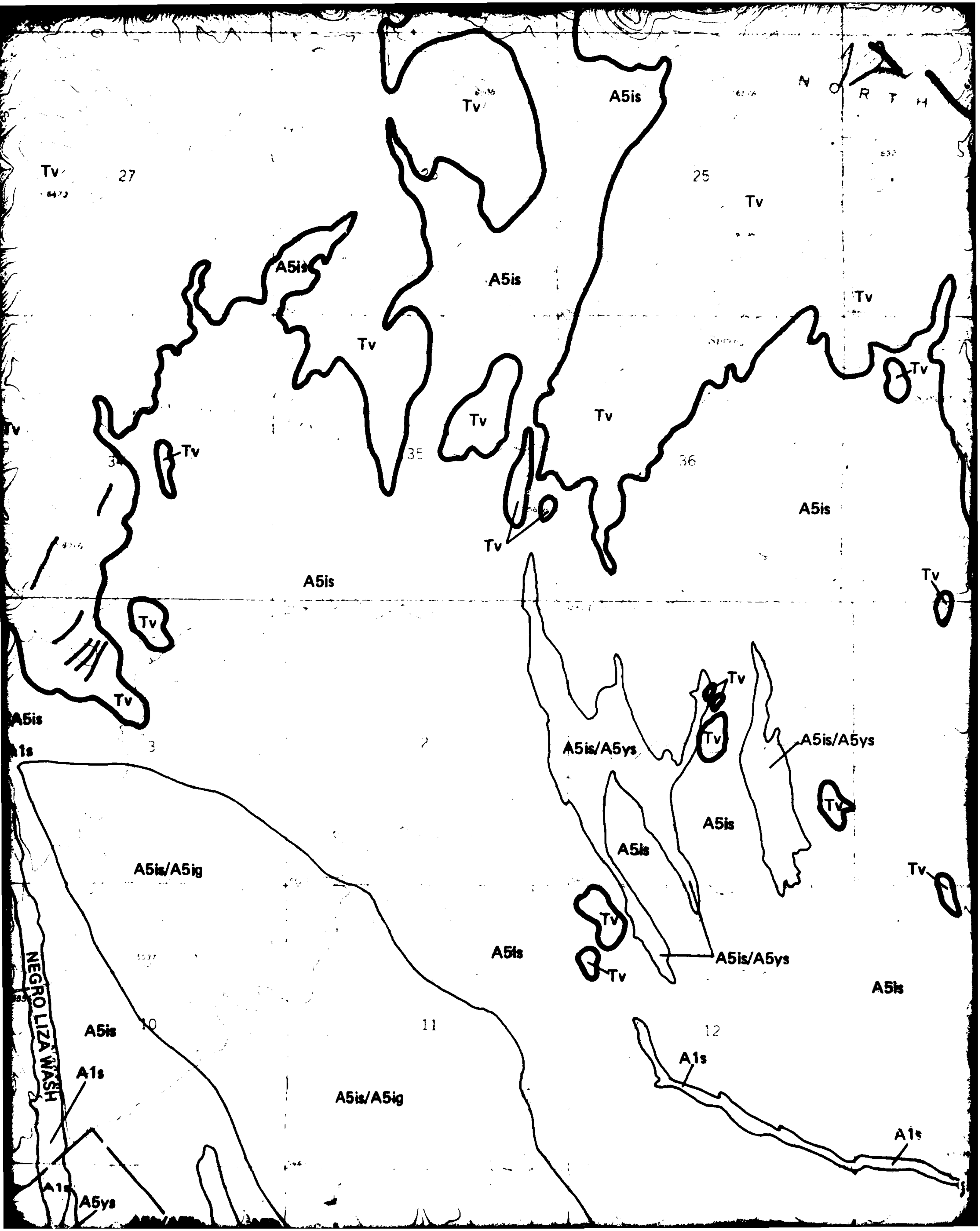


Tv
A5is
A5is
A5is
Tv
Tv
Tv
Tv
Tv
Tv
A5is
Tv
A5is
Tv
A5is
Tv
Tv
Tv
A1s
Tv
A5is
PCz
Tv
A5is
Tv
Tv
A1s
A5is
Tv
A1s
Tv
A5is
A5is
Tv
23
23
A5is
BM

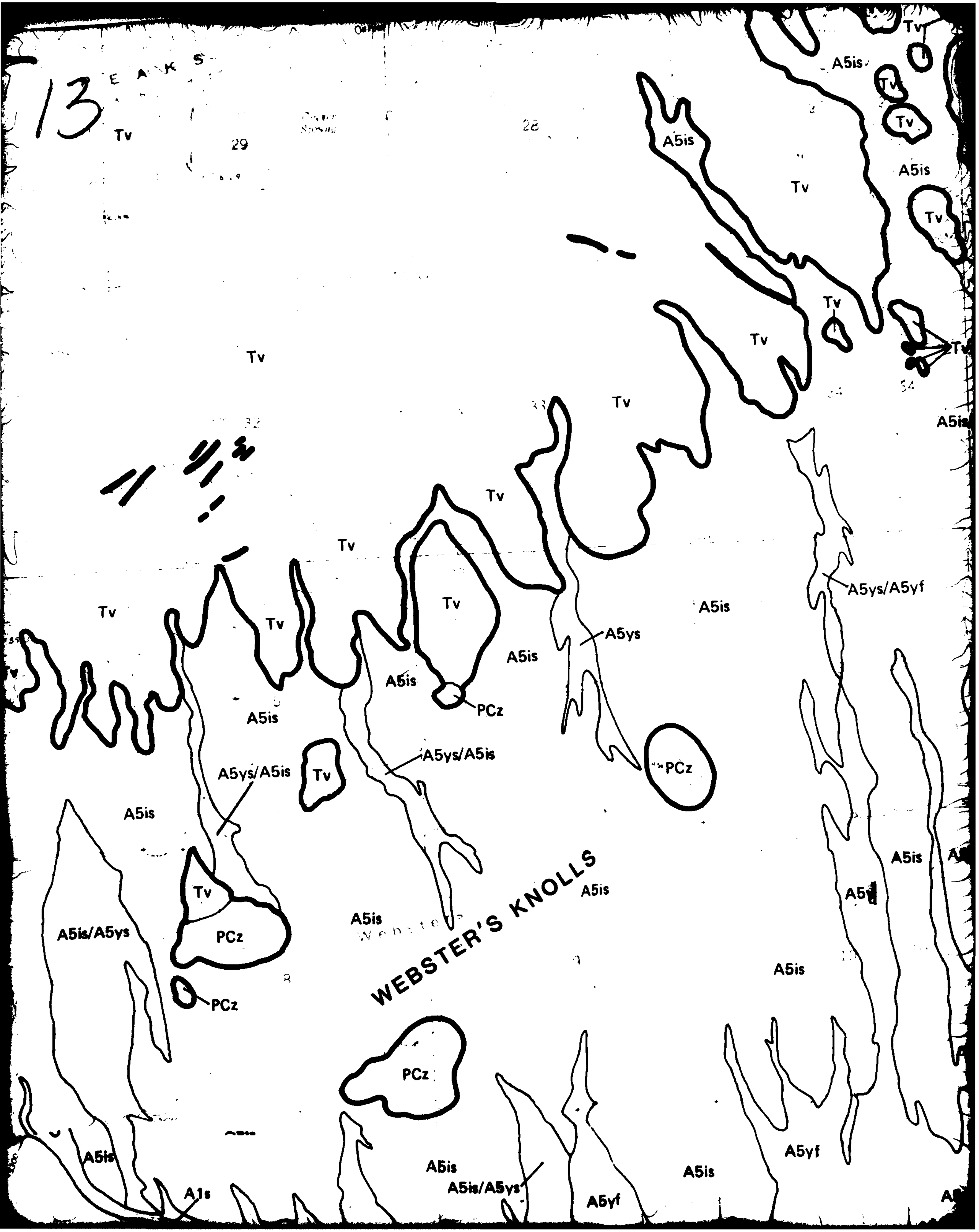

29
28
28
27
32
33
33
34
HAMBLIN PEAK
5
4
4
3
8
9
9
Tv
10
Spring

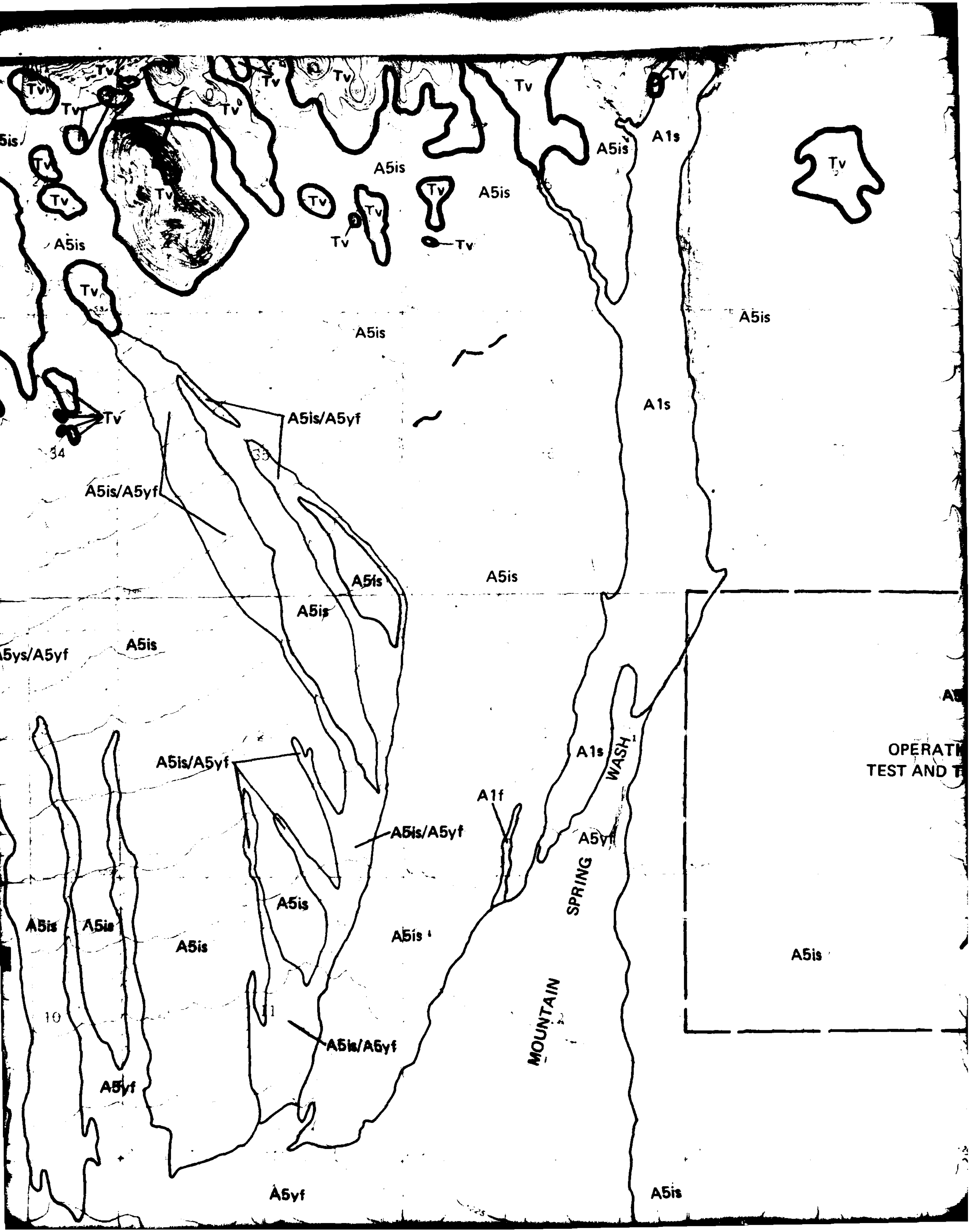

10
26
25
30
35
36
31
IN PEAK
Tv
2
1
6
Upper Trough Spring
A5og
A5ig/A5is
BASE HOUSING

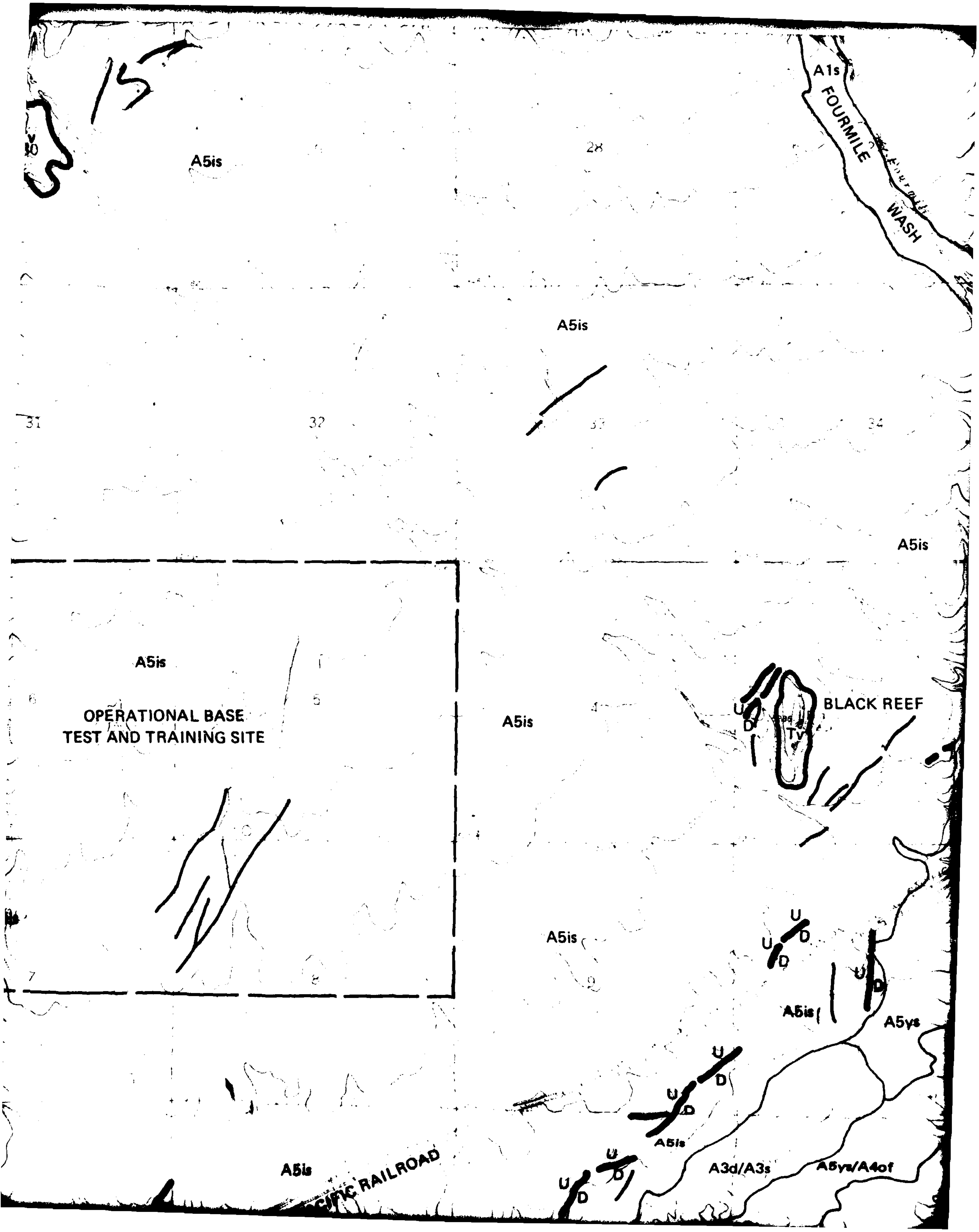

Tv
ABis
ABos
ABig/ABis
Tv
ABig/ABis
ABig/ABis
ABig/ABis

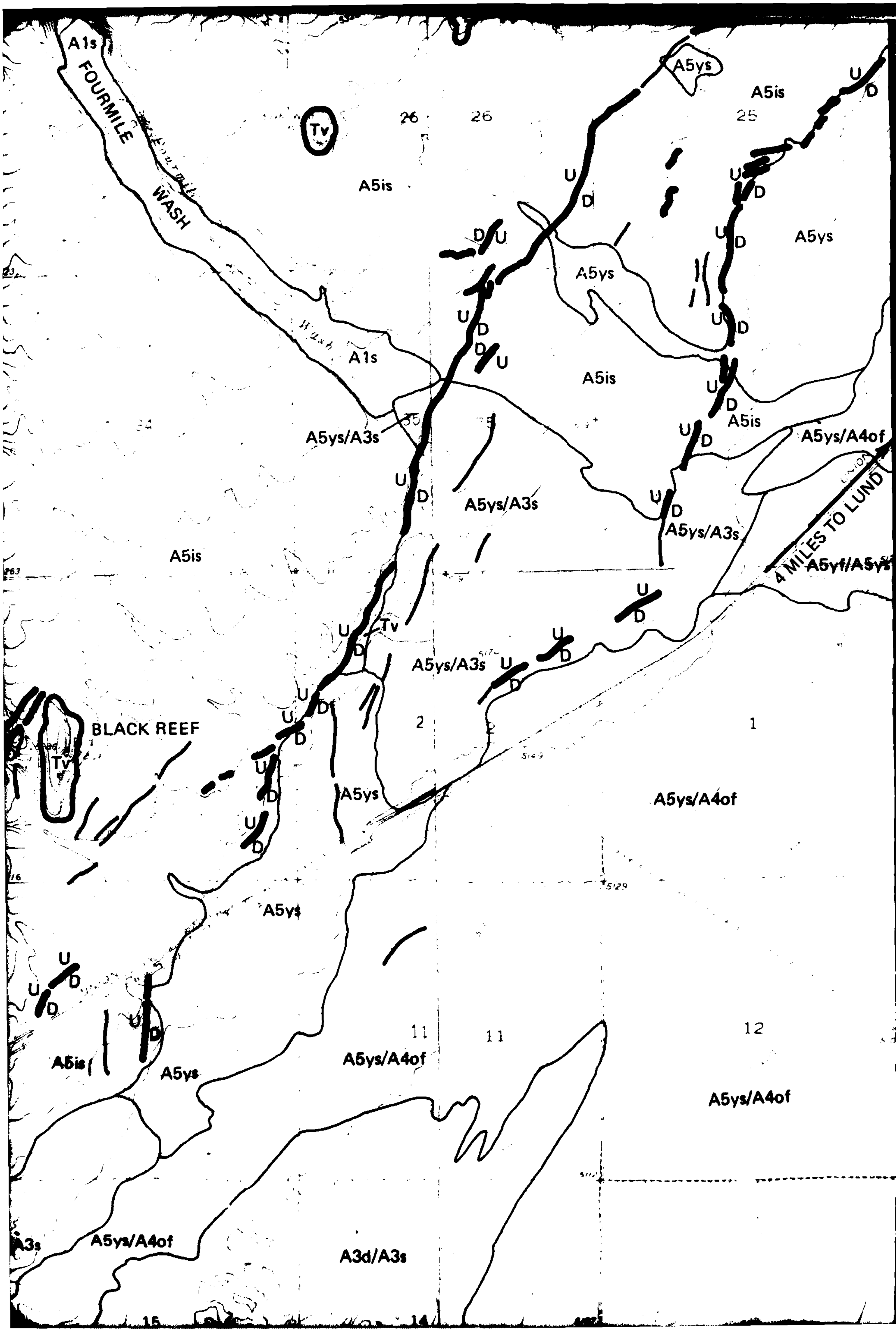


NORTH
Tv
A5is
27
25
A5is/A5ys
A5is/A5ig
A1s
A5ys
NEGRO LIZA WASH
35
36
3
10
11
12

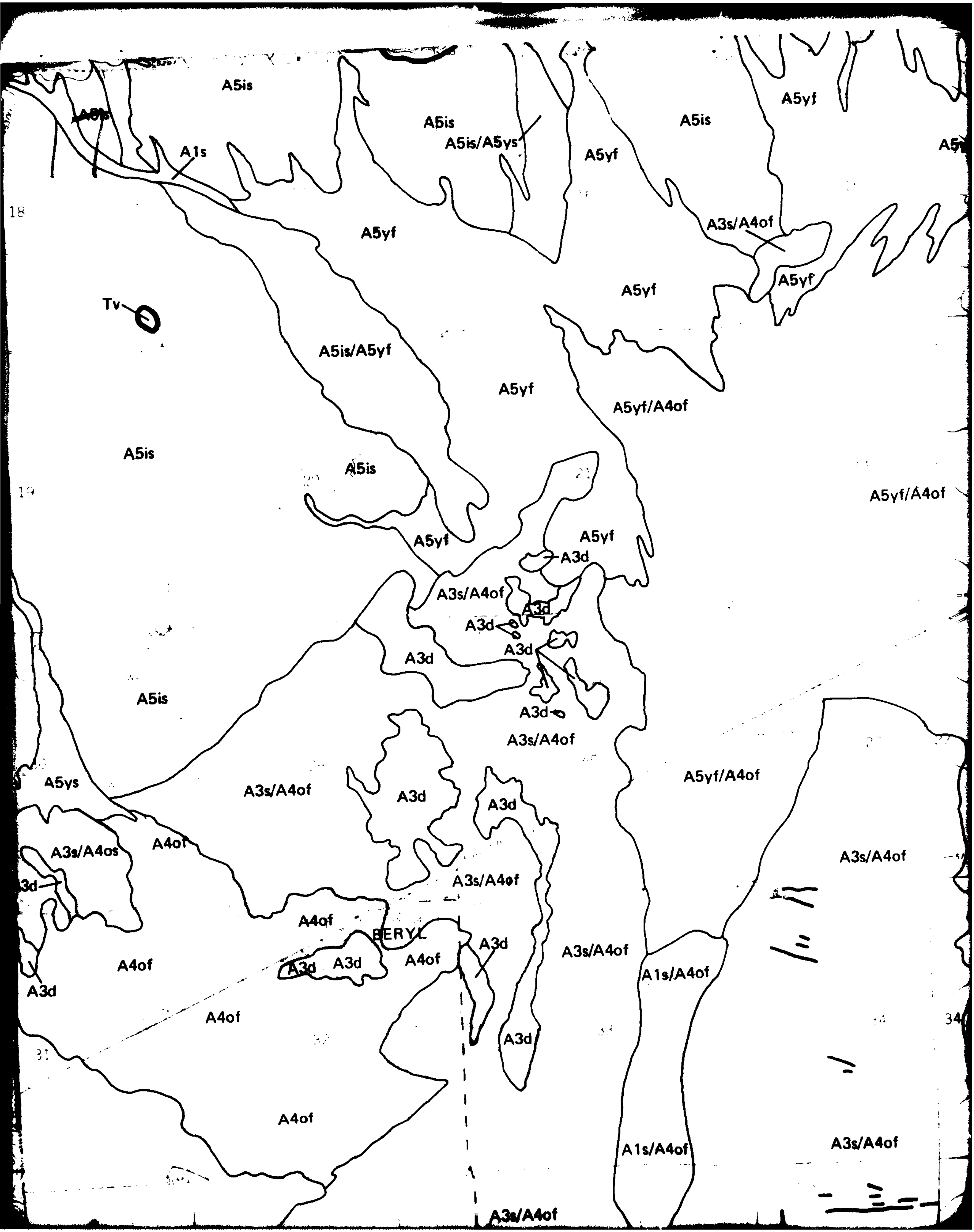

13
PEAKS
Tv
29
28
A5is
Tv
A5is
Tv
Tv
Tv
Tv
Tv
A5is
Tv
Tv
Tv
Tv
Tv
Tv
Tv
Tv
A5ys/A5yf
A5is
A5ys
A5is
A5is
PCz
A5is
A5ys/A5is
A5ys/A5is
Tv
PCz
A5is
Tv
WEBSTER'S KNOLLS
A5is
A5is
A5is/A5ys
PCz
A5is
PCz
A5is
PCz
A5is
A1s
A5is
A5is/A5ys
A5yf
A5is
A5yf

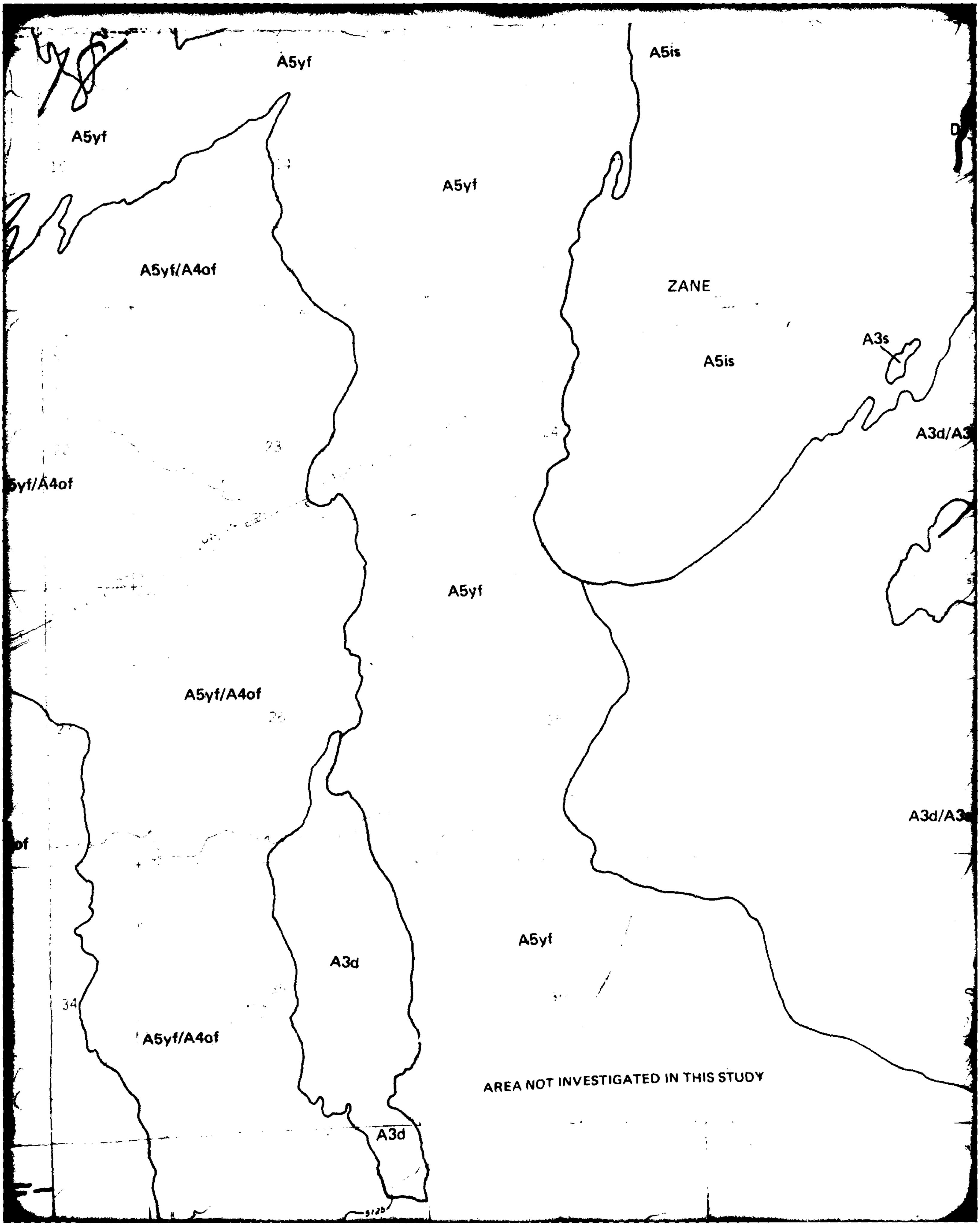

Tv
A5is
A1s
A5is/A5yf
A5ys/A5yf
A1f
A5yf
OPERATI
TEST AND T
SPRING
MOUNTAIN
WASH
34
10

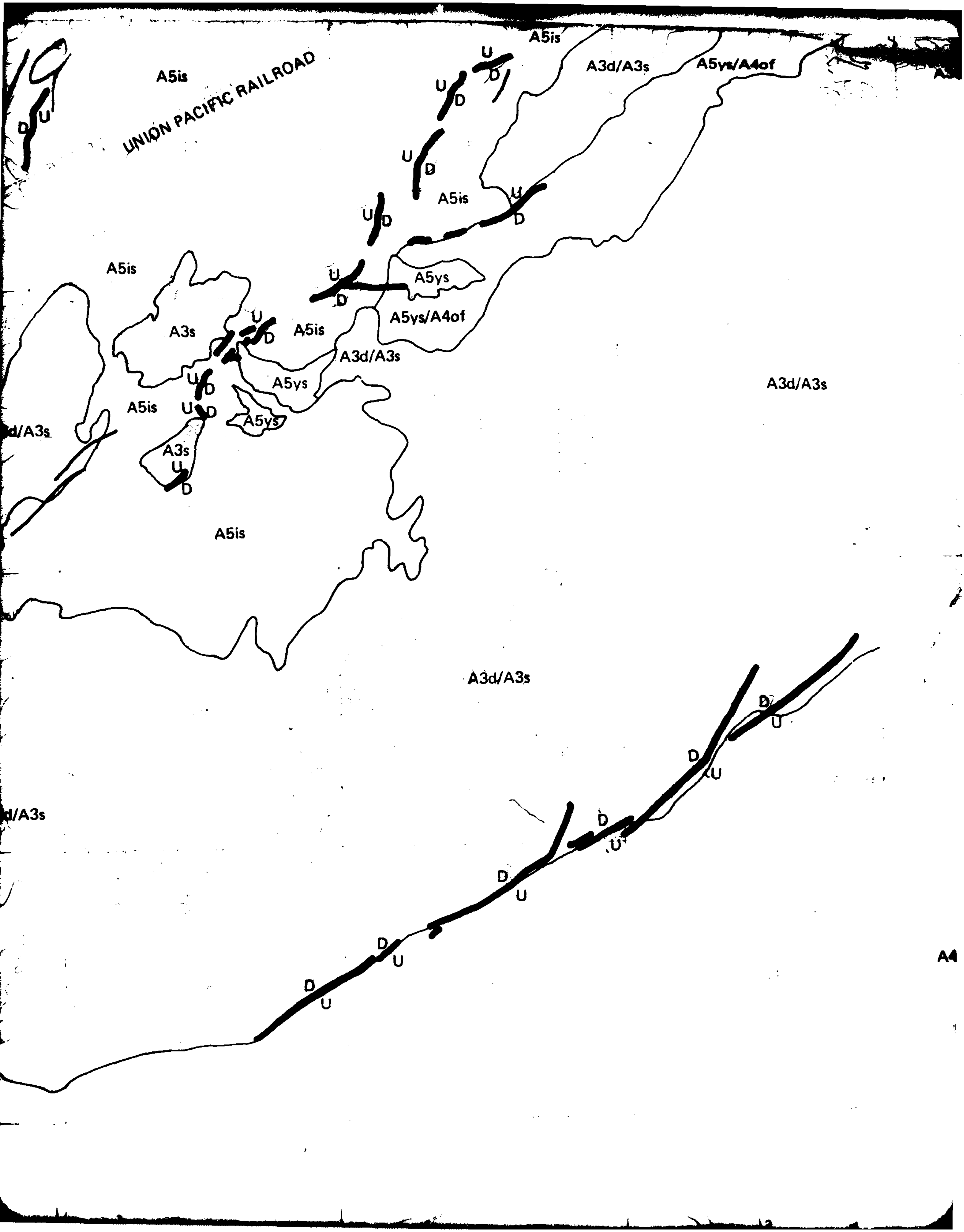

15
A5is
28
A1s
FOURMILE
WASH
A5is
31
32
34
A5is
A5is
OPERATIONAL BASE
TEST AND TRAINING SITE
A5is
BLACK REEF
U
D
Tv
A5is
U
D
U
D
U
D
A5is
A5ys
U
D
U
D
A5is
A5is
PACIFIC RAILROAD
U
D
U
D
A3d/A3s
A5ys/A4of

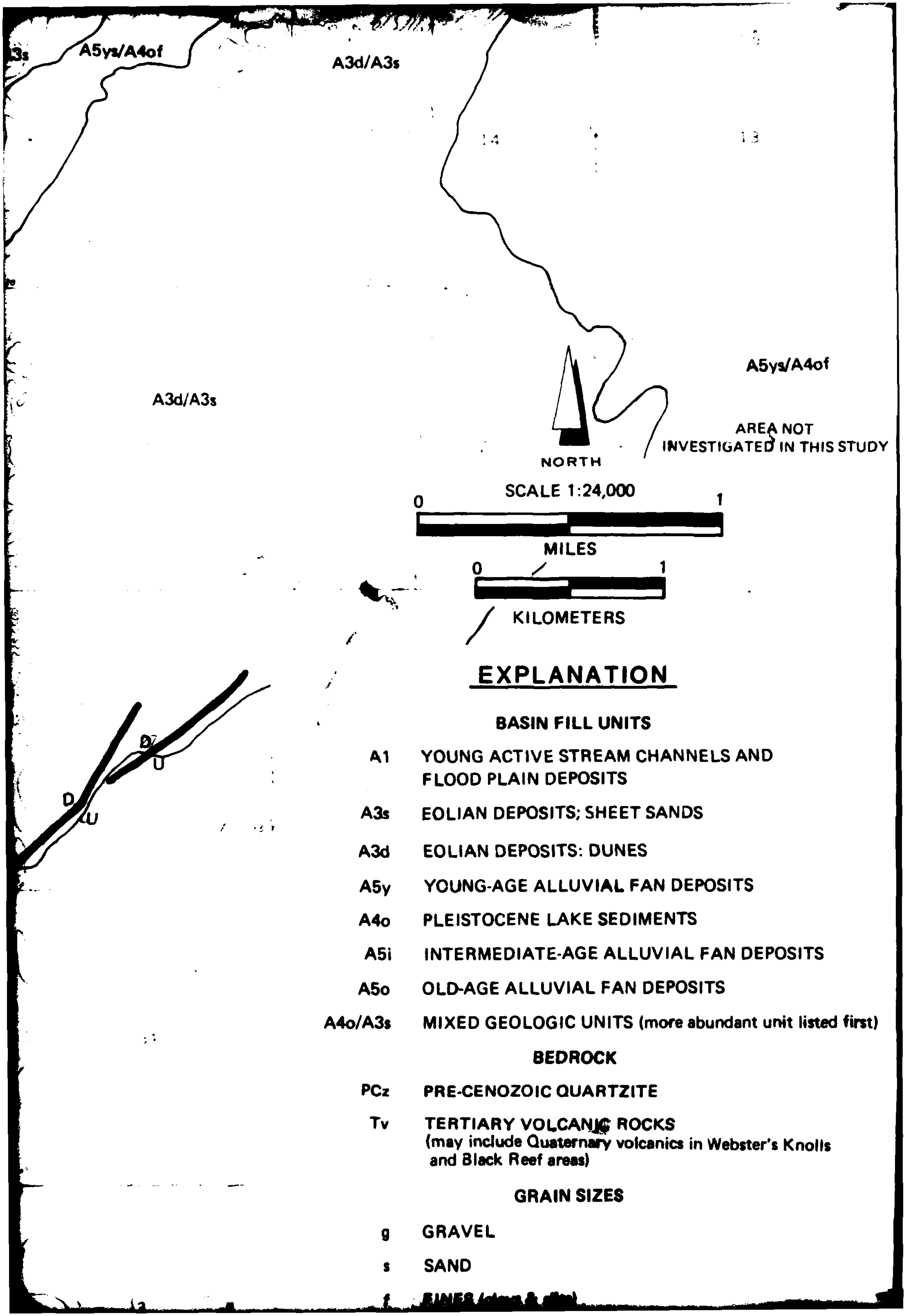

A1s
FOURMILE
WASH
Tv
26
26
25
A5ys
A5is
U
D
A5is
A5ys
A5ys
A1s
A5is
A5is
A5ys/A3s
35
A5ys/A4of
A5ys/A3s
A5ys/A3s
4 MILES TO LUND
A5yf/A5ys
A5is
Tv
A5ys/A3s
BLACK REEF
Tv
2
2
1
A5ys
A5ys/A4of
A5ys
A5is
A5ys
11
11
12
A5ys/A4of
A5ys/A4of
A3s
A5ys/A4of
A3d/A3s
15
14

16

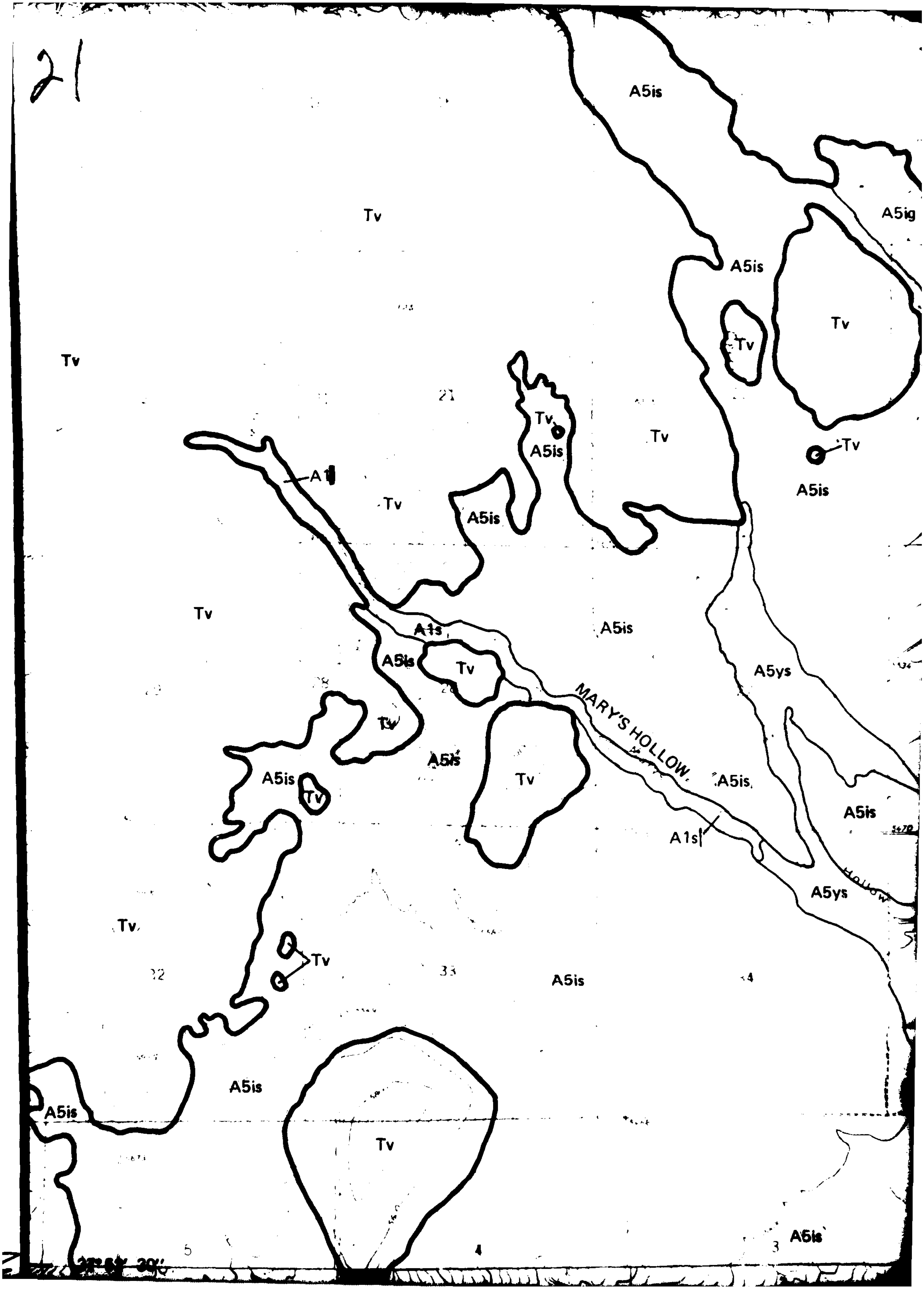

A5is
A1s
A5is
A5is/A5ys
A5yf
A5is
A5yf
18
A5yf
A3s/A4of
Tv
A5yf
A5yf
A5is/A5yf
A5yf
A5yf/A4of
A5is
A5is
19
21
A5yf/A4of
A5yf
A5yf
A3d
A3s/A4of
A3d
A3d
A3d
A3d
A5is
A3d
A3s/A4of
A5yf/A4of
A5ys
A3s/A4of
A3d
A3d
A4of
A3s/A4os
A3s/A4of
A3s/A4of
3d
A4of
BERYL
A3d
A3s/A4of
A3d
A3d
A4of
A4of
A1s/A4of
A3d
A4of
A3d
31
34
A4of
A1s/A4of
A3s/A4of
A3s/A4of


A5yf
A5is
A5yf
A5yf
A5yf/A4of
ZANE
A5is
A3s
A3d/A3
5yf/A4of
A5yf
A5yf/A4of
A3d/A3
of
A5yf
A3d
A5yf/A4of
AREA NOT INVESTIGATED IN THIS STUDY
A3d

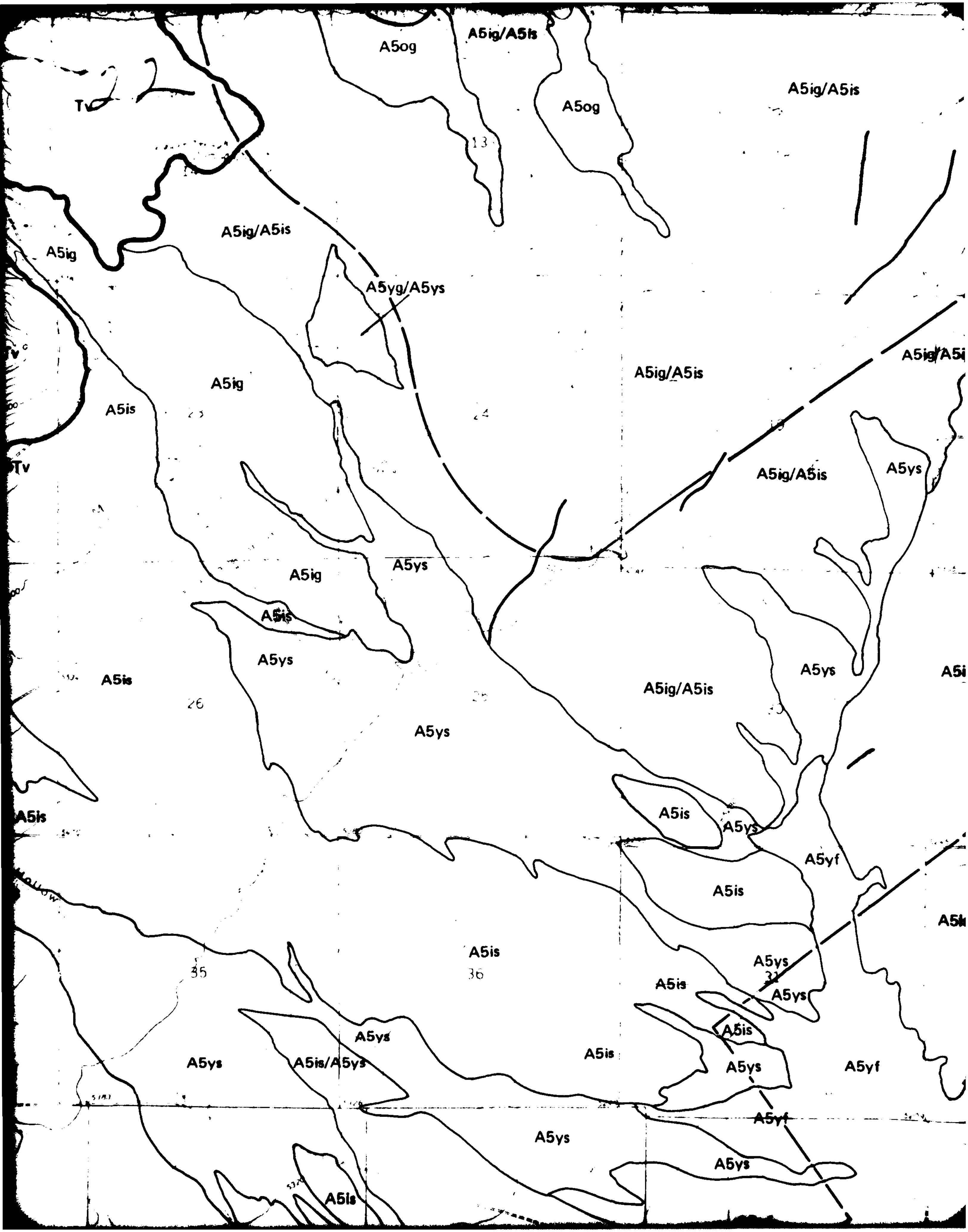

UNION PACIFIC RAILROAD
A5is
A3d/A3s
A5ys/A4of
A5ys
A3s
A5ys
A5ys/A4of
A3d/A3s
A5ys
A5is
A3s
A5ys
A5is
d/A3s
A5is
A3d/A3s
d/A3s
A4
U
D


A3s
A5ys/A4of
A3d/A3s
14
13
A3d/A3s
A5ys/A4of
AREA NOT
INVESTIGATED IN THIS STUDY
NORTH
SCALE 1:24,000
0
1
MILES
0
1
KILOMETERS
D
U
D
U
EXPLANATION
BASIN FILL UNITS
A1 YOUNG ACTIVE STREAM CHANNELS AND FLOOD PLAIN DEPOSITS
A3s EOLIAN DEPOSITS; SHEET SANDS
A3d EOLIAN DEPOSITS: DUNES
A5y YOUNG-AGE ALLUVIAL FAN DEPOSITS
A4o PLEISTOCENE LAKE SEDIMENTS
A5i INTERMEDIATE-AGE ALLUVIAL FAN DEPOSITS
A5o OLD-AGE ALLUVIAL FAN DEPOSITS
A4o/A3s MIXED GEOLOGIC UNITS (more abundant unit listed first)
BEDROCK
PCz PRE-CENOZOIC QUARTZITE
Tv TERTIARY VOLCANIC ROCKS (may include Quaternary volcanics in Webster's Knolls and Black Reef areas)
GRAIN SIZES
g GRAVEL
s SAND

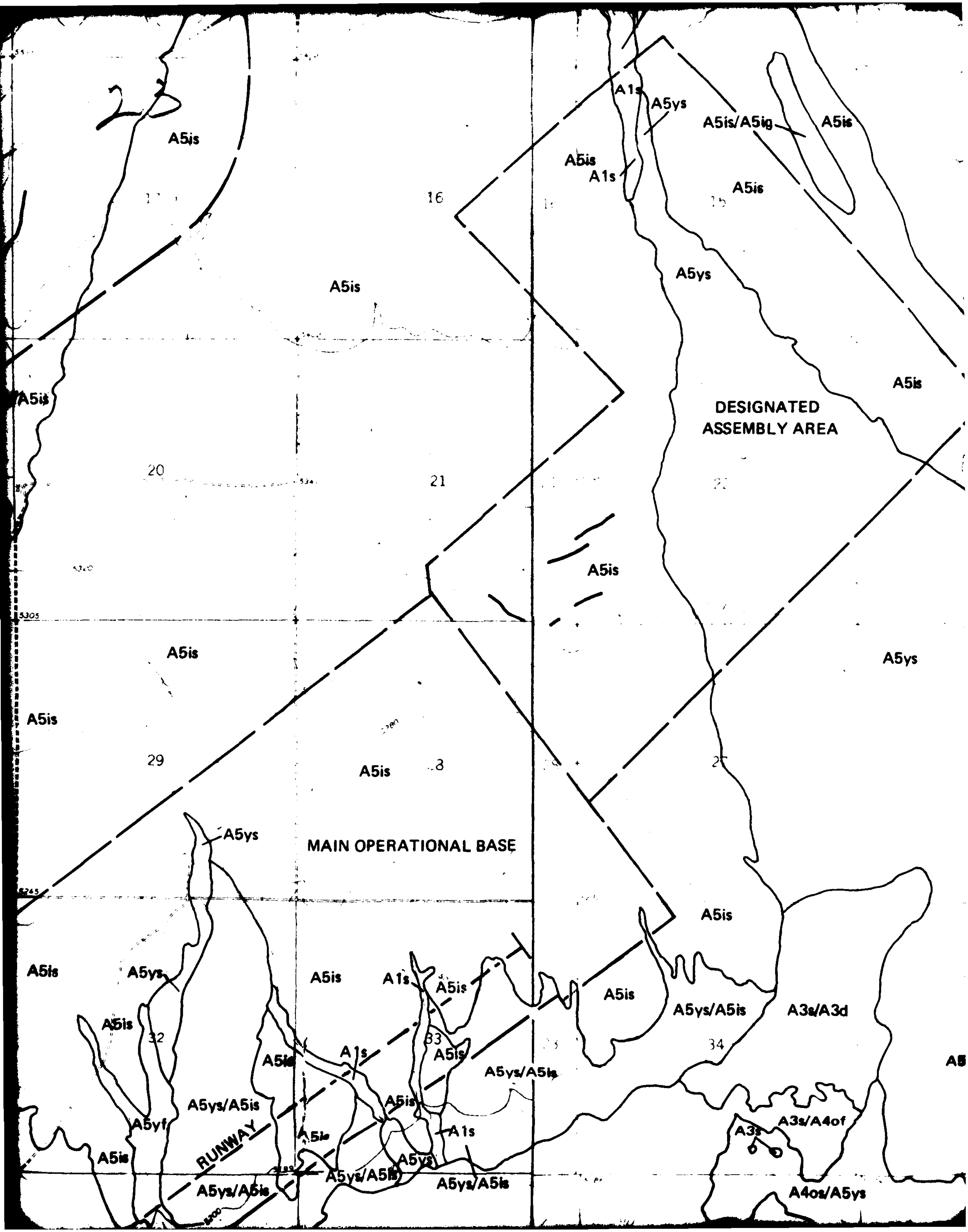
21

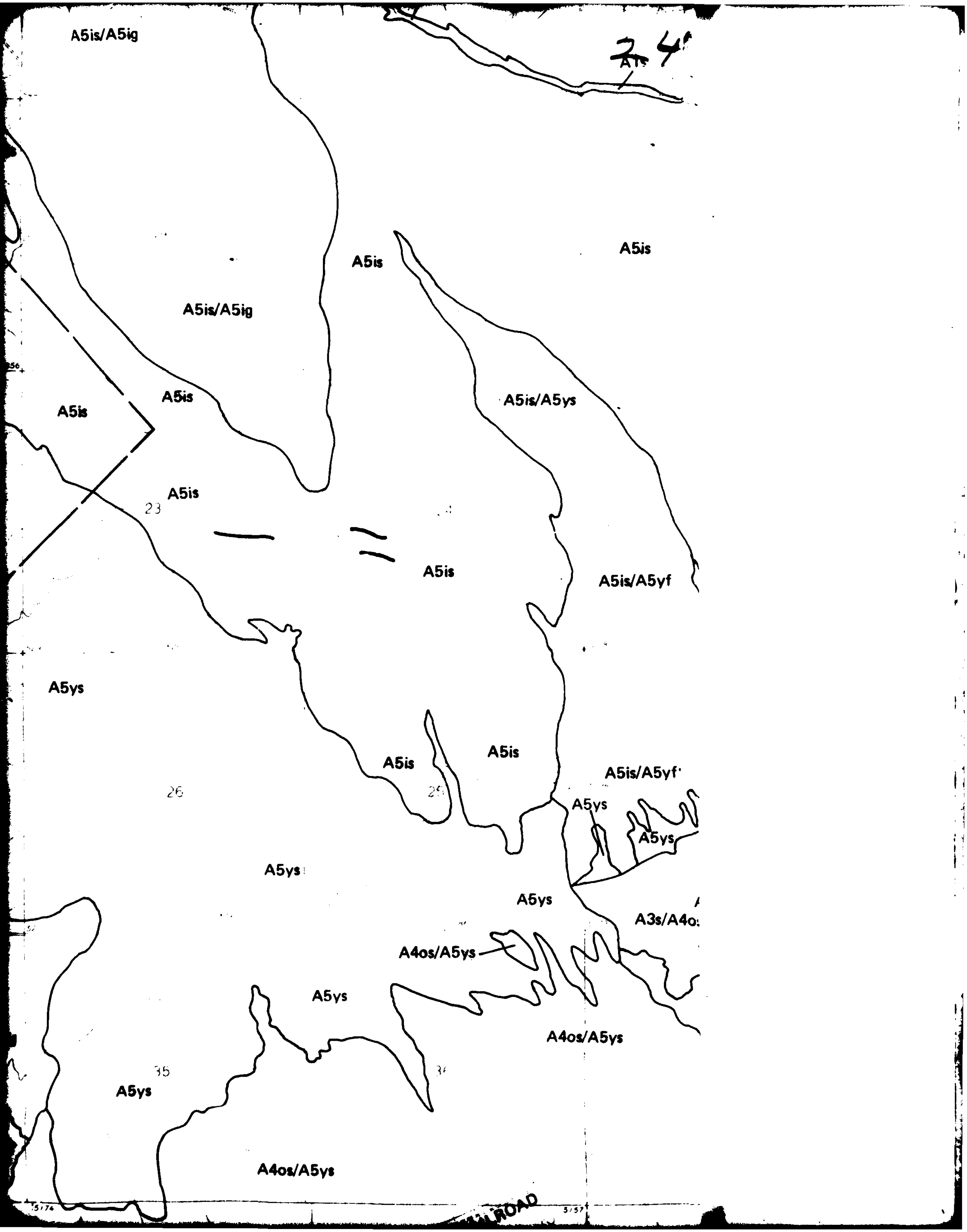


A5is
A5ig
Tv
A5is
Tv
Tv
Tv
21
Tv
A5is
Tv
Tv
A5is
A1
Tv
A5is
Tv
A5is
A1s
A5is
Tv
A5ys
MARY'S HOLLOW
Tv
A5is
Tv
A5is
A5is
Tv
A1s
A5is
Hollow
A5ys
Tv
Tv
33
A5is
A5is
A5is
Tv
A5is
5
4
3

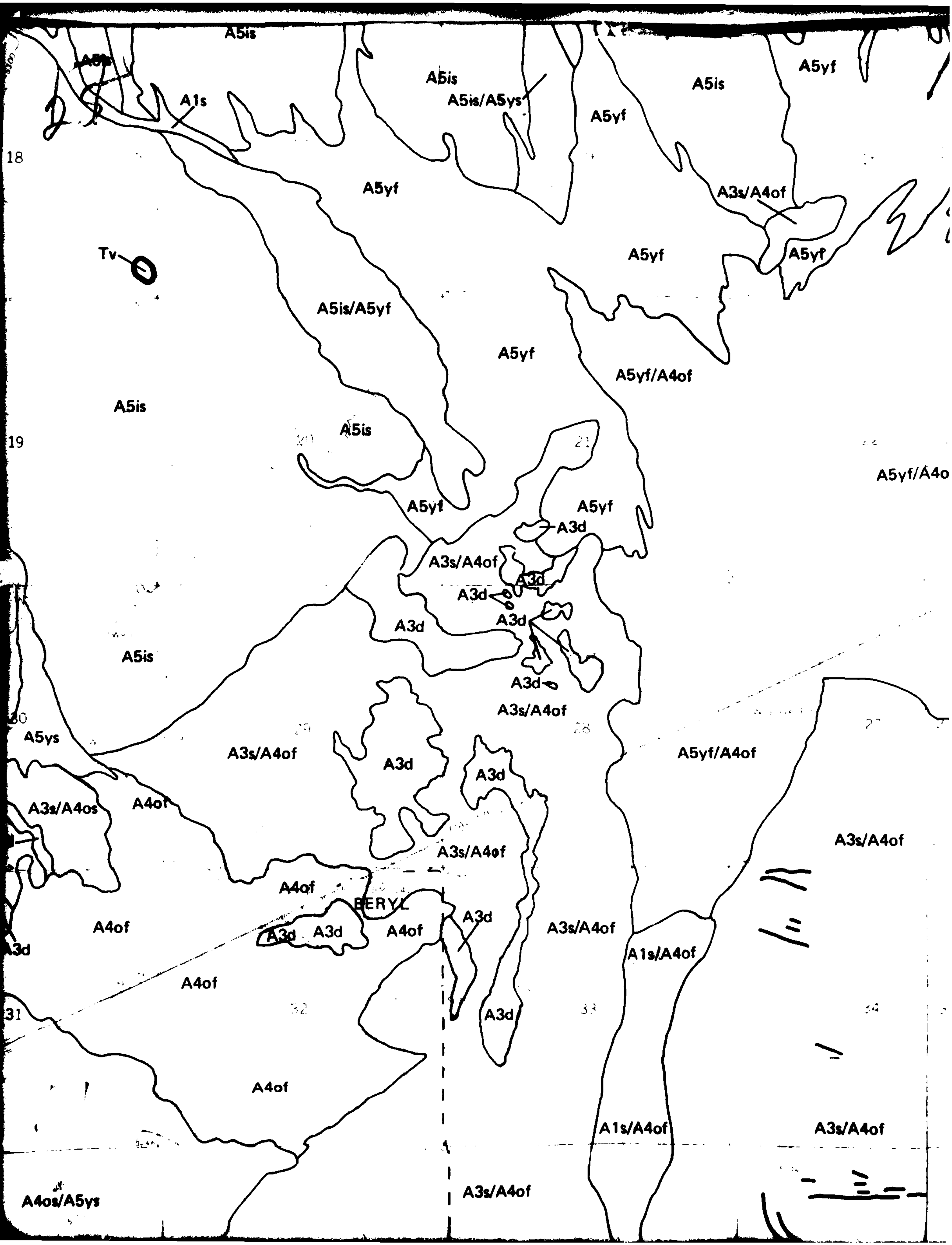


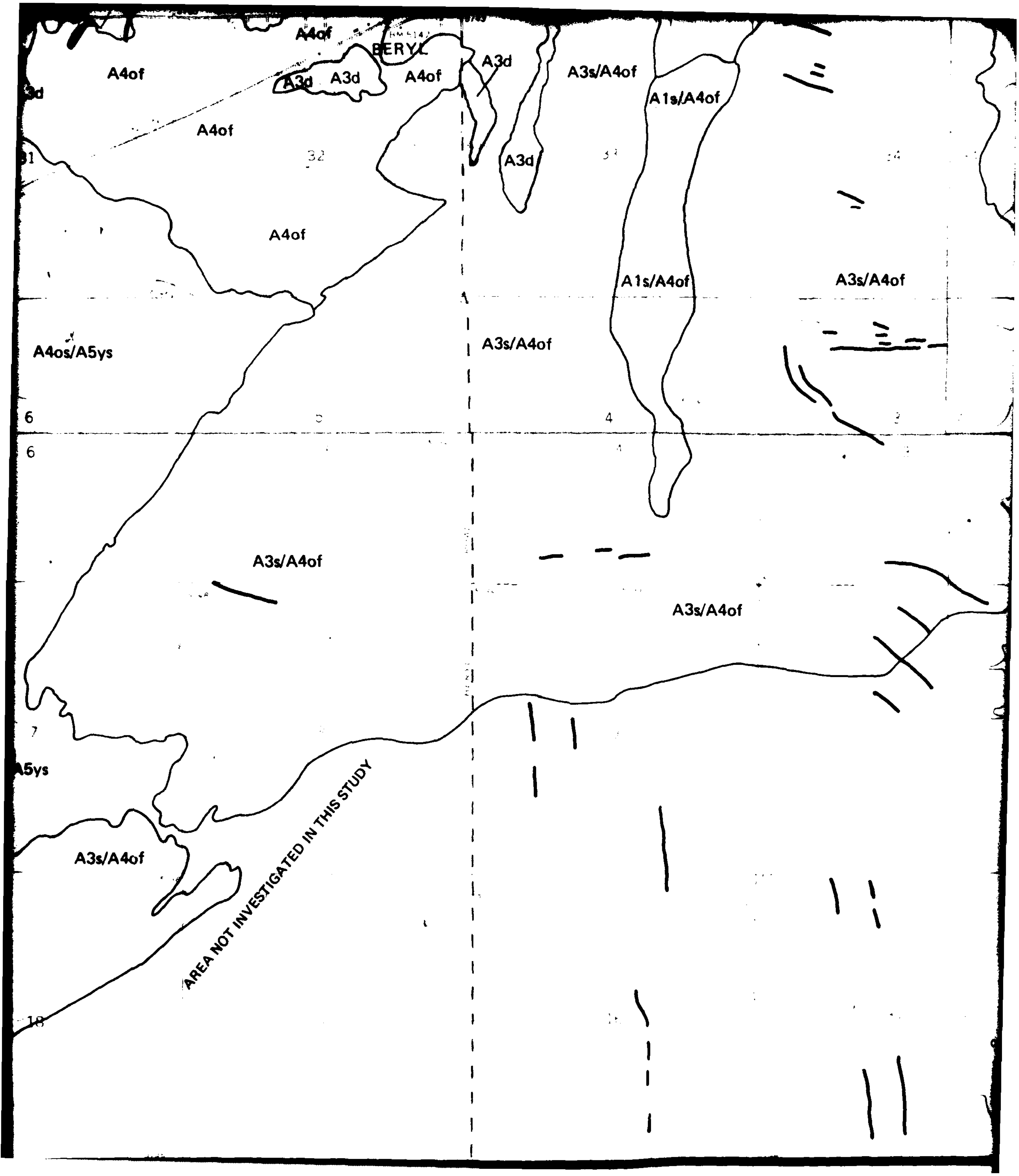
A5og
A5ig/A5is
A5og
A5ig/A5is
Tv
13
A5ig/A5is
A5ig
A5yg/A5ys
Tv
A5ig
A5is
A5ig/A5is
24
A5ig/A5is
A5ys
Tv
A5ig
A5ys
A5is
A5ys
A5is
26
A5ys
A5ig/A5is
A5ys
A5is
A5is
A5ys
A5yf
A5is
A5is
A5ys
35
36
A5is
A5ys
A5is
A5ys
A5ys
A5is/A5ys
A5is
A5ys
A5yf
A5yf
A5ys
A5ys
A5is

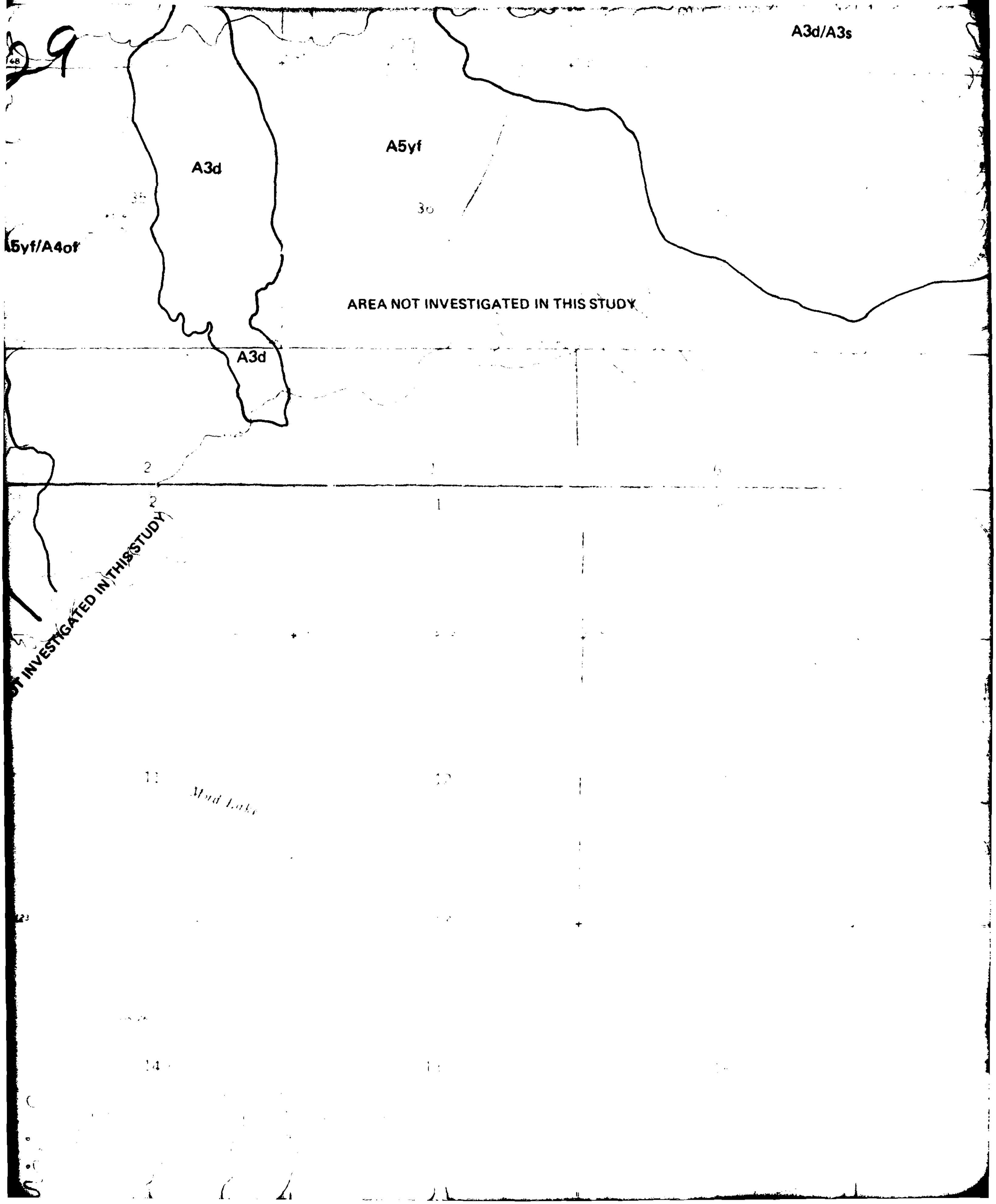

A1s
A5ys
A5is/A5ig
A5is
A5is
A5is
A1s
A5is
16
A5is
A5ys
A5is
DESIGNATED
ASSEMBLY AREA
20
21
A5is
A5is
A5ys
A5is
29
A5is
A5ys
MAIN OPERATIONAL BASE
A5is
A5is
A5ys
A5is
A1s
A5is
A5is
A5ys/A5is
A3s/A3d
A5is
32
A1s
33
A5is
34
A5is
A5ys/A5is
A5ys/A5is
A5is
A3s/A4of
A5yf
A1s
A3s
A5is
RUNWAY
A5ys
A5ys/A5is
A5ys/A5is
A5ys/A5is
A4os/A5ys



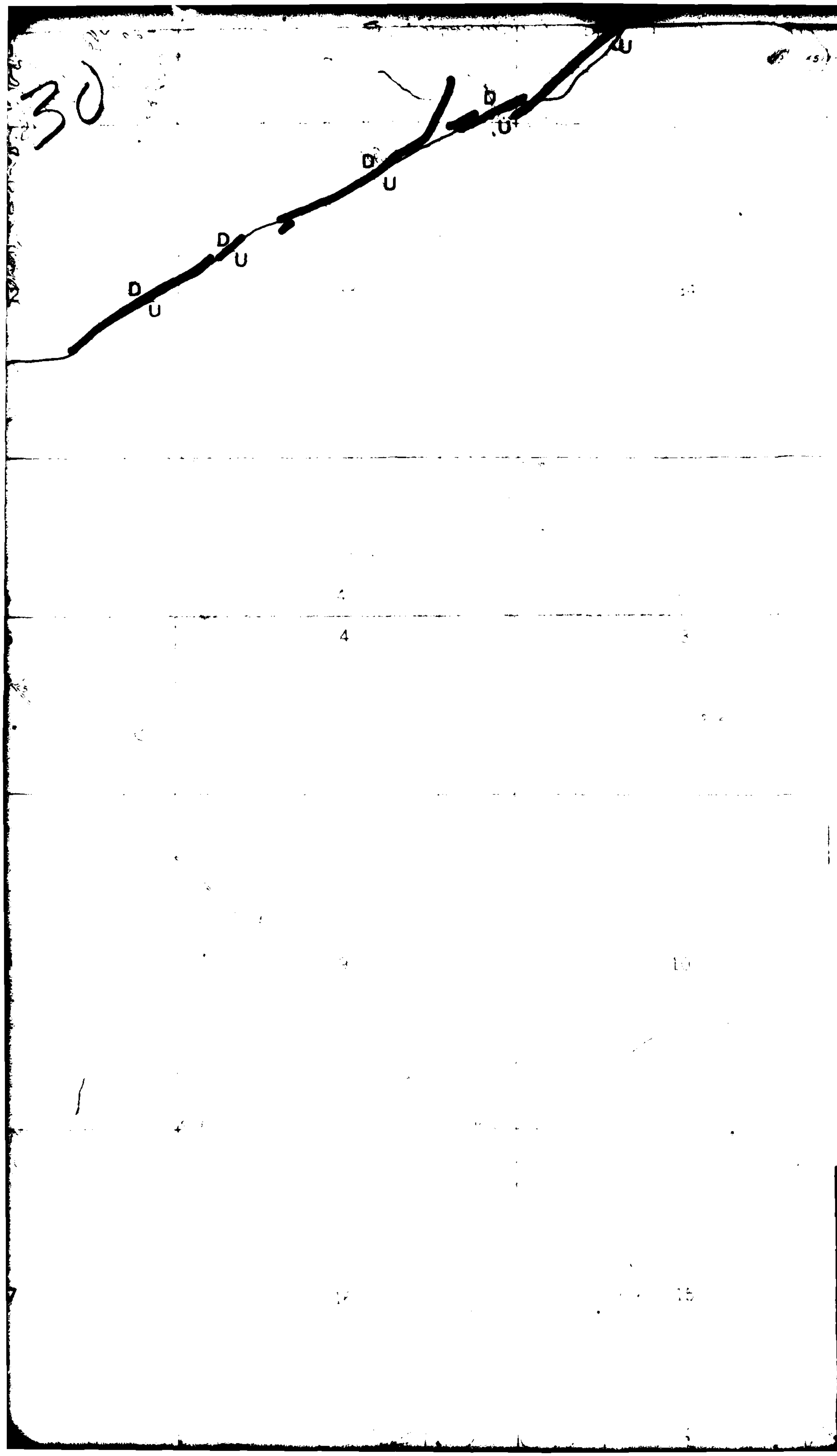
A5is/A5ig
A5is/A5ig
A5is
A5is
A5is
A5is
A5is
A5is/A5ys
A5is
A5is/A5yf
A5is
A5is
A5is/A5yf
A5ys
A5ys
A5ys
A5ys
A5ys
A3s/A4o
A4os/A5ys
A5ys
A4os/A5ys
A5ys
A4os/A5ys
23
26
35
ROAD


A5is
A1s
A5is
A5is/A5ys
A5is
A5yf
A5yf
18
A5yf
A3s/A4of
Tv
A5yf
A5yf
A5is/A5yf
A5yf
A5yf/A4of
A5is
A5is
19
20
21
A5yf/A4o
A5yf
A5yf
A3d
A3s/A4of
A3d
A3d
A3d
A3d
A5is
A3d
A3s/A4of
30
A5ys
29
28
A3s/A4of
A5yf/A4of
A3d
A3d
A3s/A4os
A4of
A3s/A4of
A3s/A4of
A4of
BERYL
A3d
A4of
A3d
A3d
A4of
A3s/A4of
A3d
A1s/A4of
A4of
31
32
A3d
33
34
A4of
A1s/A4of
A3s/A4of
A4os/A5ys
A3s/A4of


A4of
BERYL
A3d
A4of
A3d
A3d
A4of
A3d
A3s/A4of
A1s/A4of
A4of
32
A3d
A4of
A1s/A4of
A3s/A4of
A4os/A5ys
A3s/A4of
6
4
6
A3s/A4of
A3s/A4of
7
A5ys
A3s/A4of
AREA NOT INVESTIGATED IN THIS STUDY
18


9
A3d/A3s
A5yf
A3d
5yf/A4of
AREA NOT INVESTIGATED IN THIS STUDY
A3d
NOT INVESTIGATED IN THIS STUDY
2
2
1
Mud Lake

30



A3s	EOLIAN DEPOS
A3d	EOLIAN DEPOS
A5y	YOUNG-AGE AL
A4o	PLEISTOCENE L
A5i	INTERMEDIATE
A5o	OLD-AGE ALLU
A4o/A3s	MIXED GEOLOG

BE

PCz	PRE-CENOZOIC
Tv	TERTIARY VOL (may include Qu and Black Reef a

GRAI

g	GRAVEL
s	SAND
f	FINES (clays & s
A5is/A5ig	DENOTES LATER VARIATIONS

SYM

PROPOSED ACTI (APPROXIMATEL

CONTACT BETW

CONTACT BETW

U / D FAULT TRACE; D U - upthrown bloc

LINEAMENTS

70 STRIKE AND DI

GEOL
OPERATIO
BER

MX SITING INVES
DEPARTMENT OF THE A

31

A3s	EOLIAN DEPOSITS; SHEET SANDS
A3d	EOLIAN DEPOSITS: DUNES
A5y	YOUNG-AGE ALLUVIAL FAN DEPOSITS
A4o	PLEISTOCENE LAKE SEDIMENTS
A5i	INTERMEDIATE-AGE ALLUVIAL FAN DEPOSITS
A5o	OLD-AGE ALLUVIAL FAN DEPOSITS
A4o/A3s	MIXED GEOLOGIC UNITS (more abundant unit listed first)

BEDROCK

PCz	PRE-CENOZOIC QUARTZITE
Tv	TERTIARY VOLCANIC ROCKS (may include Quaternary volcanics in Webster's Knolls and Black Reef areas)

GRAIN SIZES

g	GRAVEL
s	SAND
f	FINES (clays & silts)
A5is/A5ig	DENOTES LATERAL AND VERTICAL GRAIN SIZE VARIATIONS

SYMBOLS

PROPOSED ACTIVITY CENTER BOUNDARY (APPROXIMATELY LOCATED)

CONTACT BETWEEN BEDROCK AND BASIN FILL UNITS

CONTACT BETWEEN BASIN FILL UNITS

U / D — FAULT TRACE; DOTTED WHERE INFERRED
U - upthrown block; D - downthrown block

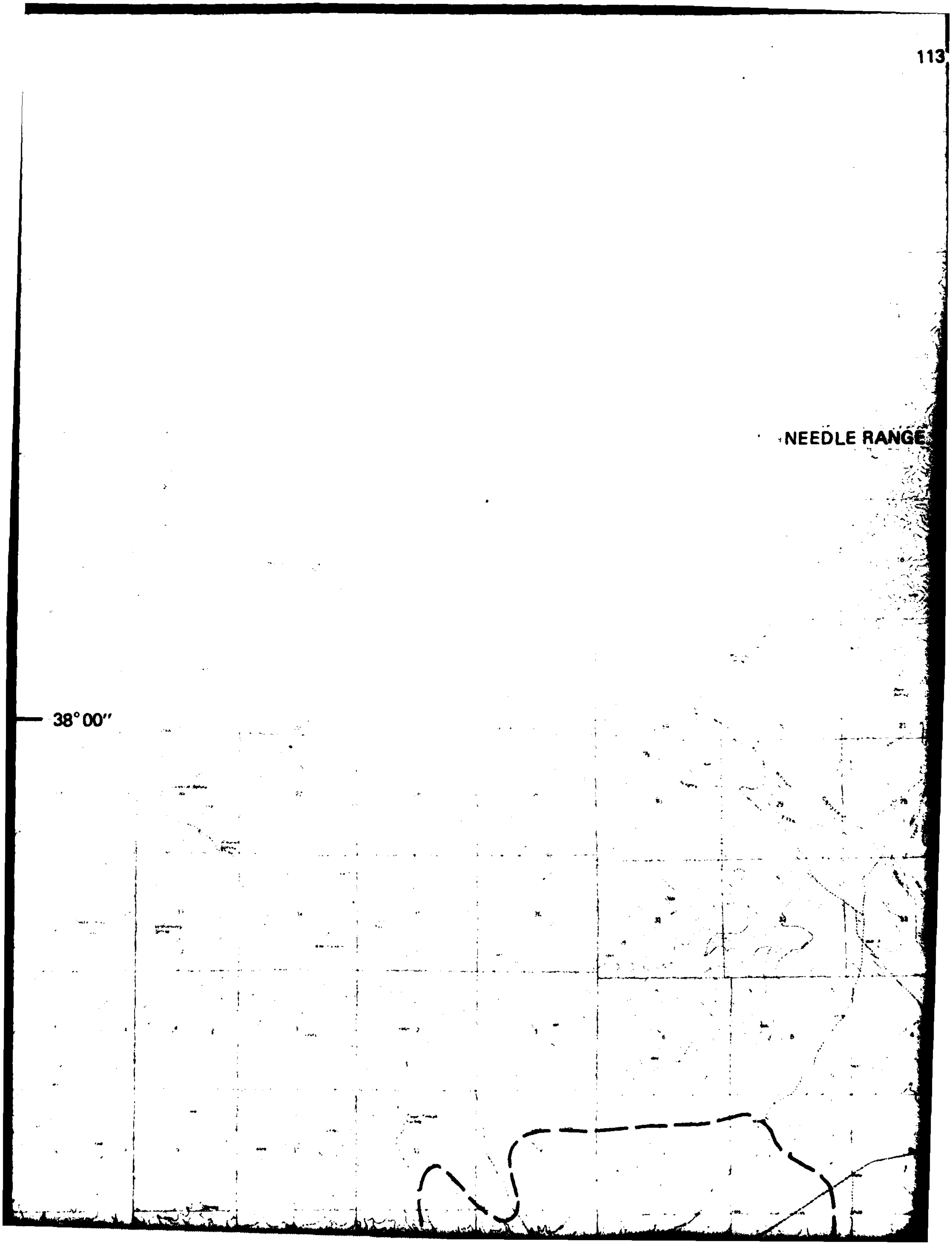
LINEAMENTS

70 — STRIKE AND DIP OF BEDDING

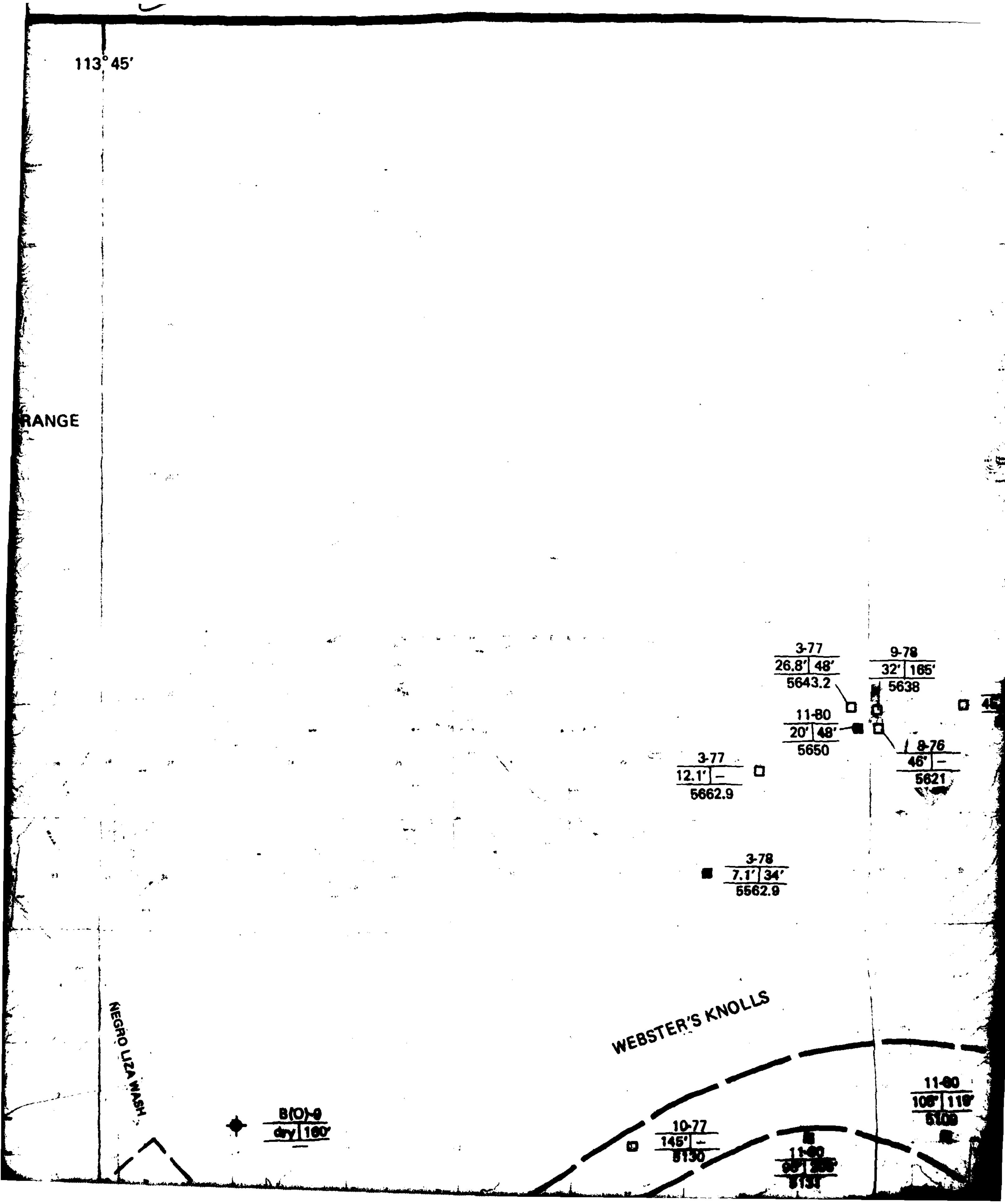
GEOLOGIC MAP
OPERATIONAL BASE SITE, BERYL, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

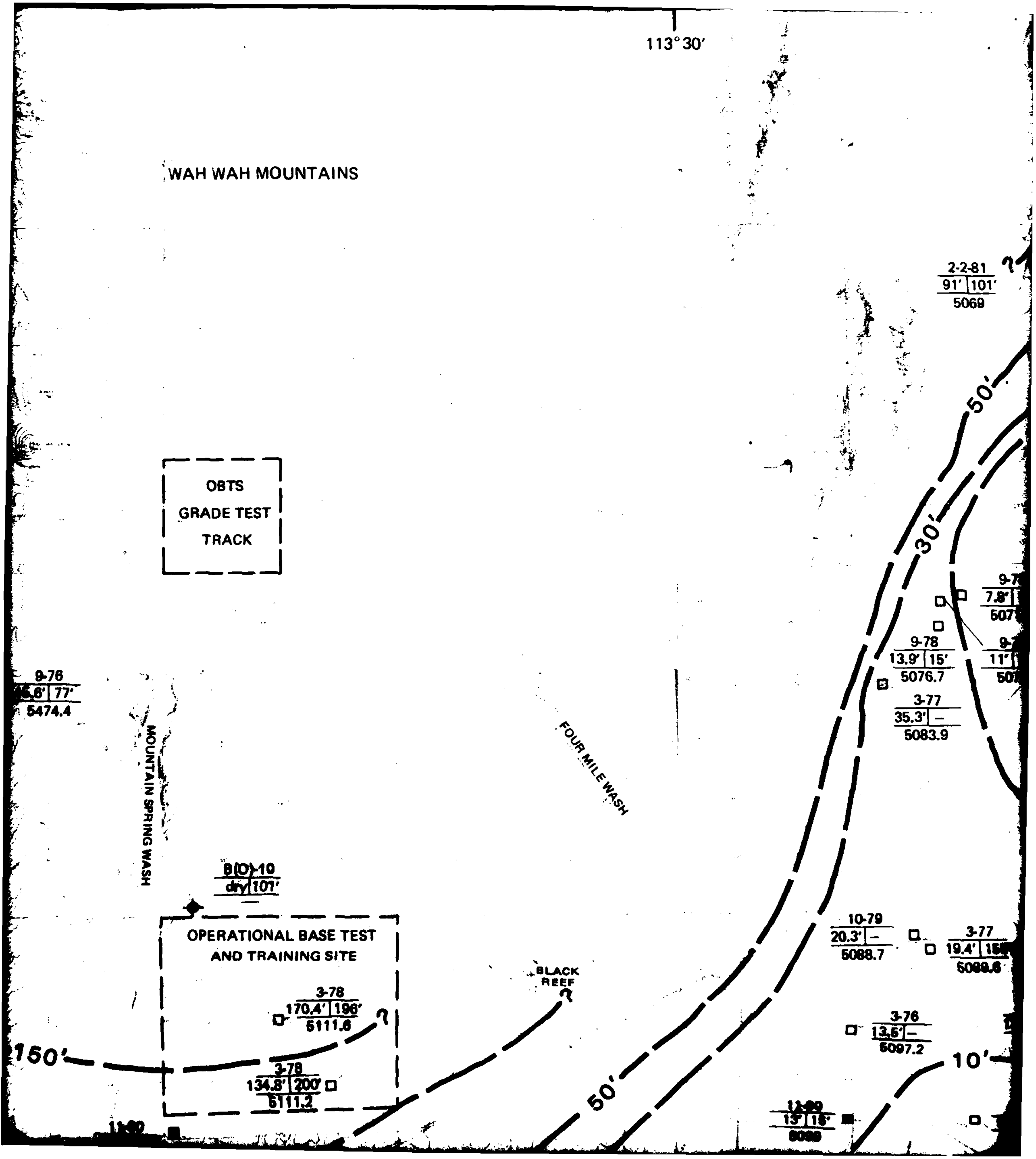
DRAWING 5–1



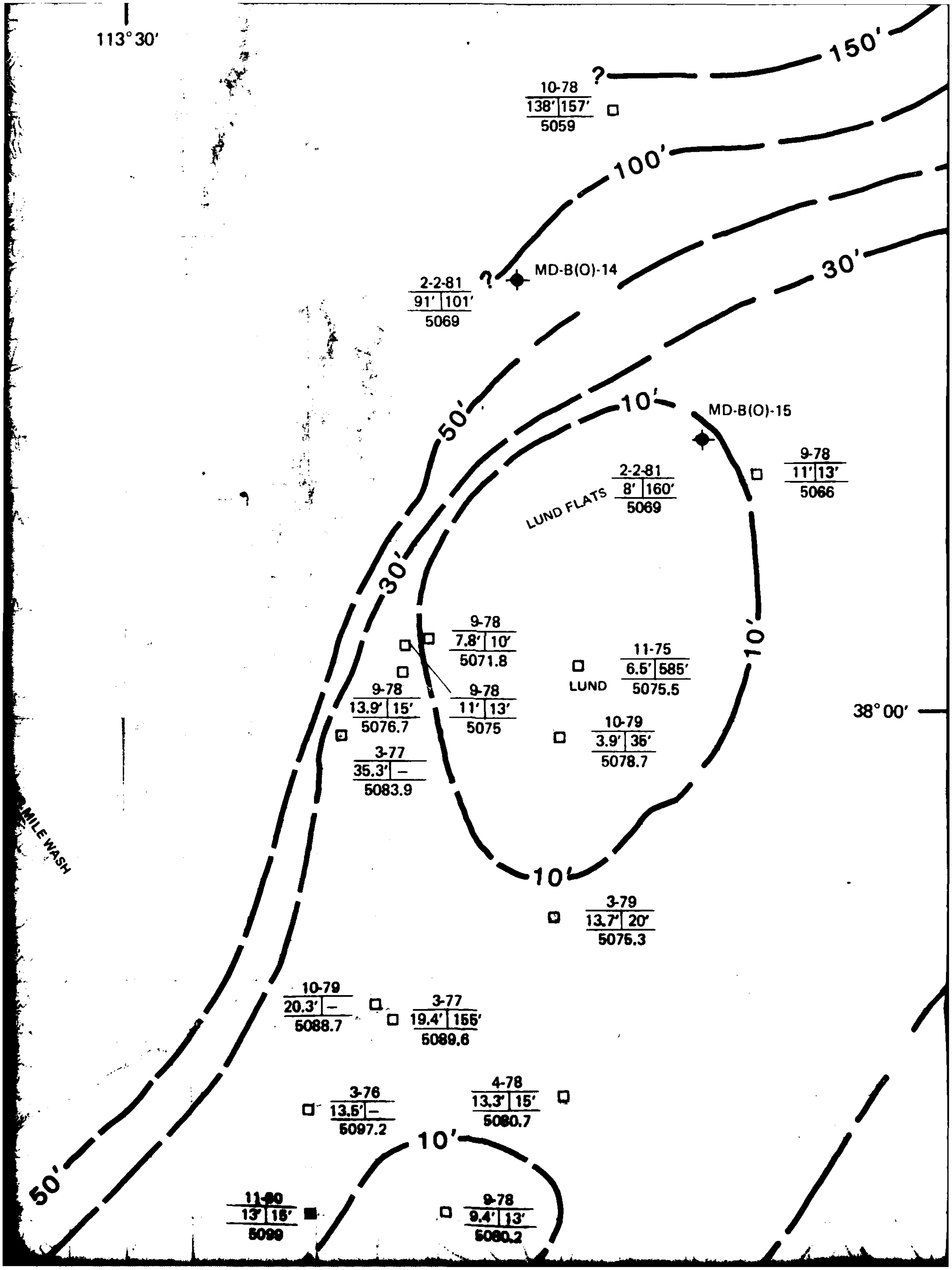
113
NEEDLE RANGE
38° 00″



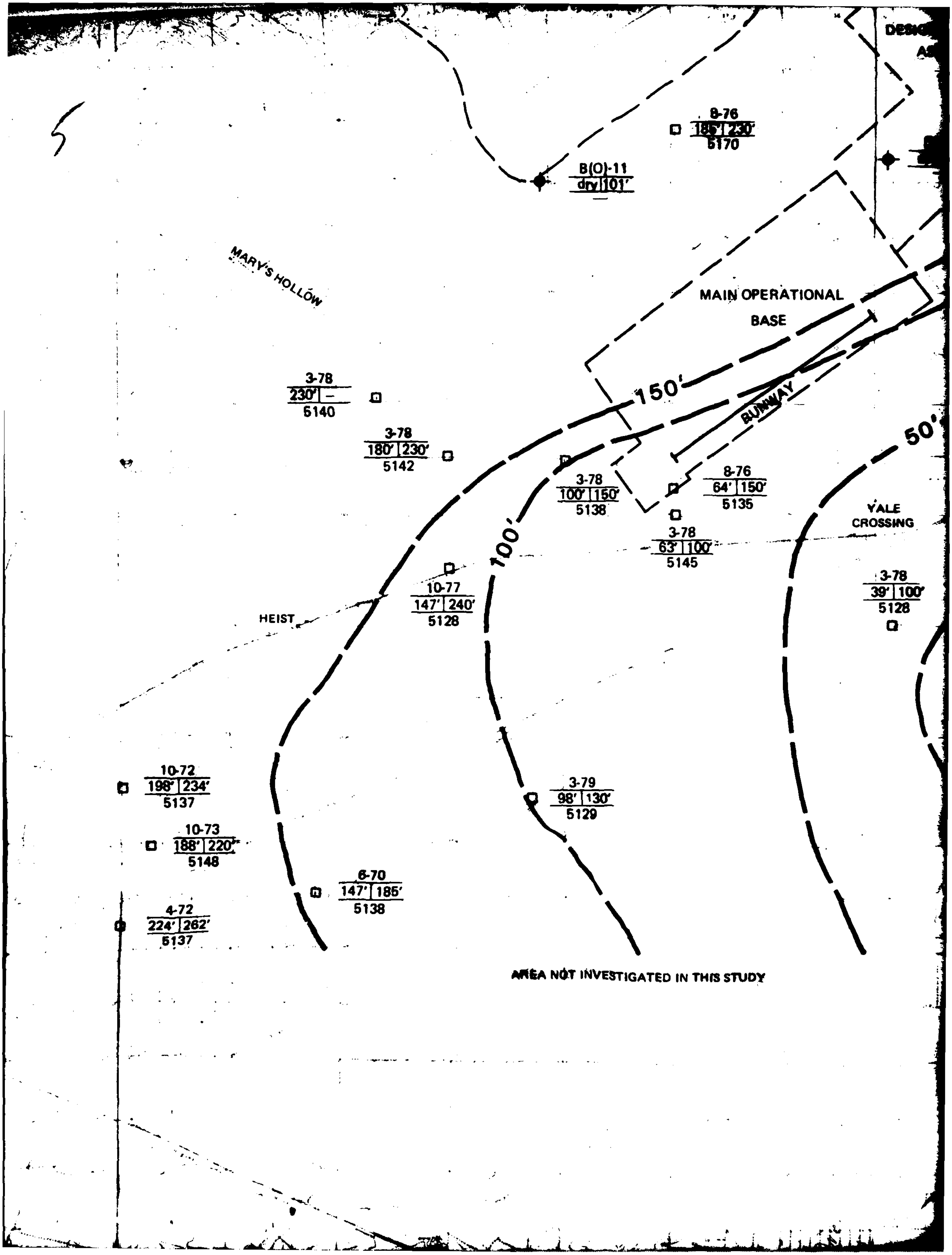
113° 45'
RANGE
3-77
26.8' 48'
5643.2
9-78
32' 165'
5638
11-80
20' 48'
5650
8-76
46' –
5621
3-77
12.1' –
5662.9
3-78
7.1' 34'
5562.9
WEBSTER'S KNOLLS
NEGRO LIZA WASH
B(O)-9
dry 160'
10-77
145' –
5130
11-80
11-80



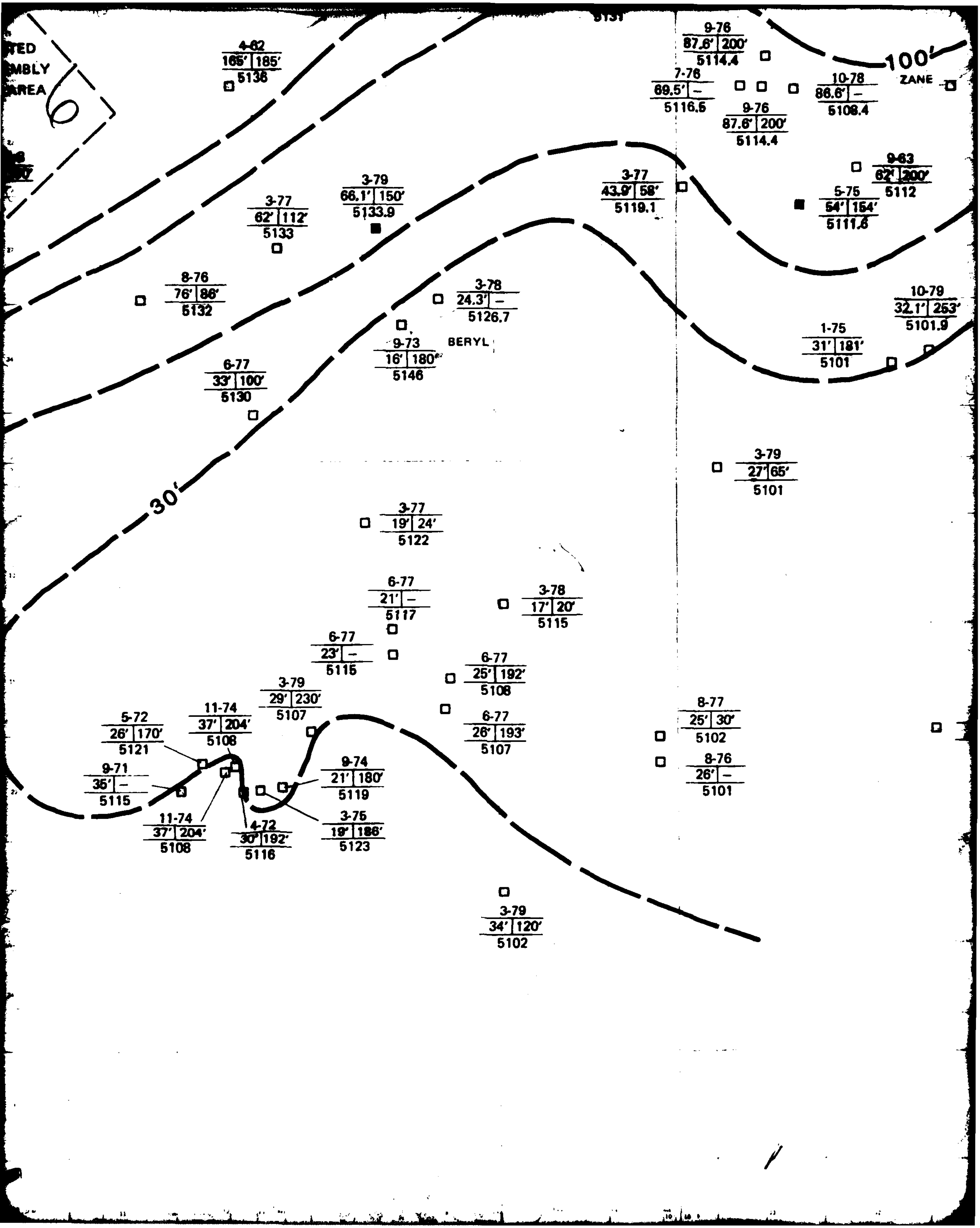
113°30′
WAH WAH MOUNTAINS
OBTS
GRADE TEST
TRACK
2-2-81
91′ 101′
5069
50′
30′
9-78
13.9′ 15′
5076.7
3-77
35.3′ –
5083.9
9-76
77′
5474.4
MOUNTAIN SPRING WASH
FOUR MILE WASH
B(O)-10
dry 101′
OPERATIONAL BASE TEST
AND TRAINING SITE
BLACK
REEF
3-78
170.4′ 196′
5111.6
150′
3-78
134.8′ 200′
5111.2
50′
10-79
20.3′ –
5088.7
3-77
19.4′
3-76
13.5′ –
5097.2
10′



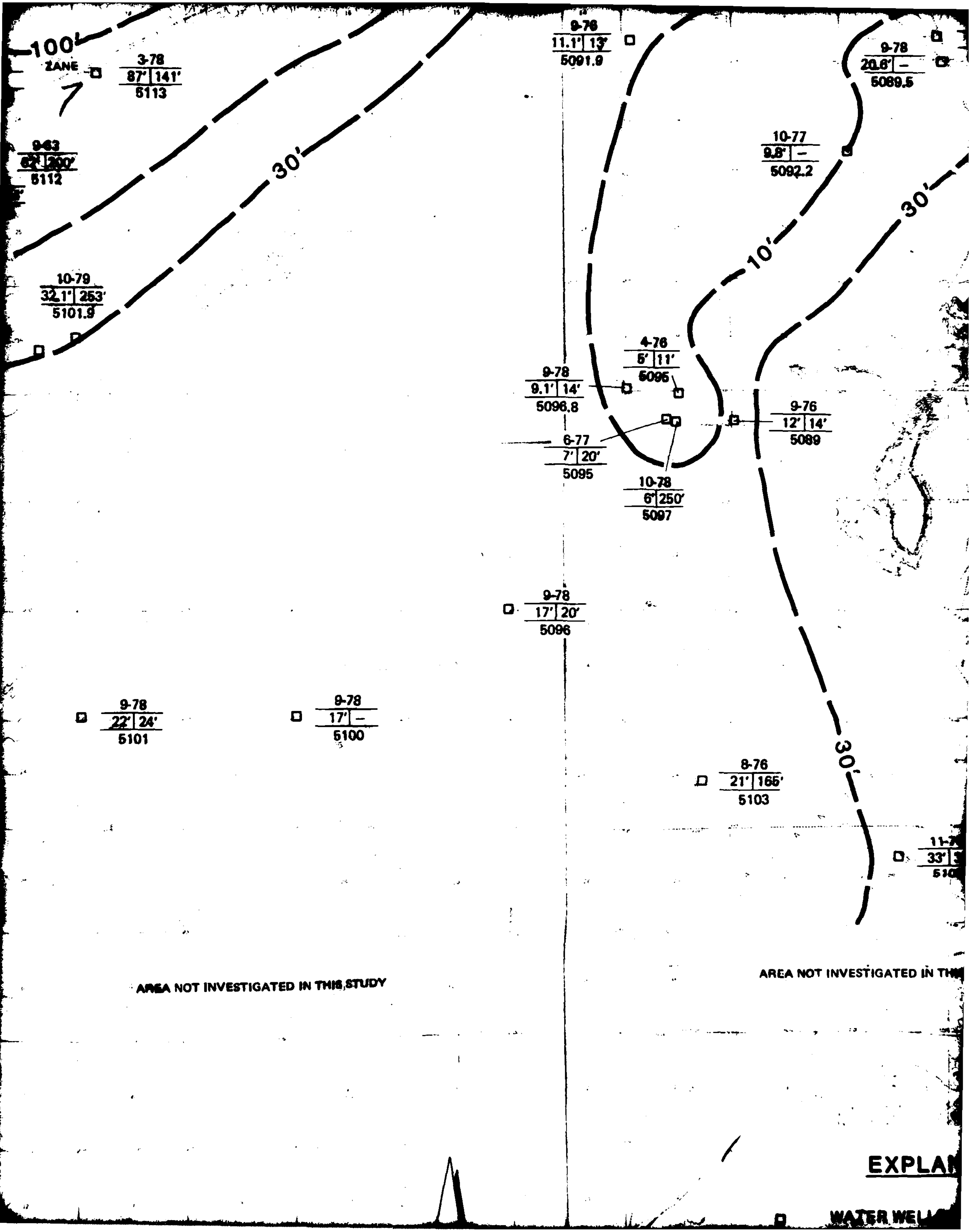
113° 30′
150′
100′
50′
30′
10′
10-78
138′ 157′
5059
MD-B(O)-14
2-2-81
91′ 101′
5069
MD-B(O)-15
9-78
11′ 13′
5066
LUND FLATS
2-2-81
8′ 160′
5069
9-78
7.8′ 10′
5071.8
11-75
6.5′ 585′
5075.5
LUND
9-78
13.9′ 15′
5076.7
9-78
11′ 13′
5075
10-79
3.9′ 35′
5078.7
38° 00′
3-77
35.3′ –
5083.9
MILE WASH
3-79
13.7′ 20′
5076.3
10-79
20.3′ –
5088.7
3-77
19.4′ 155′
5089.6
3-76
13.5′ –
5097.2
4-78
13.3′ 15′
5080.7
11-80
13′ 15′
5099
9-78
9.4′ 13′
5080.2

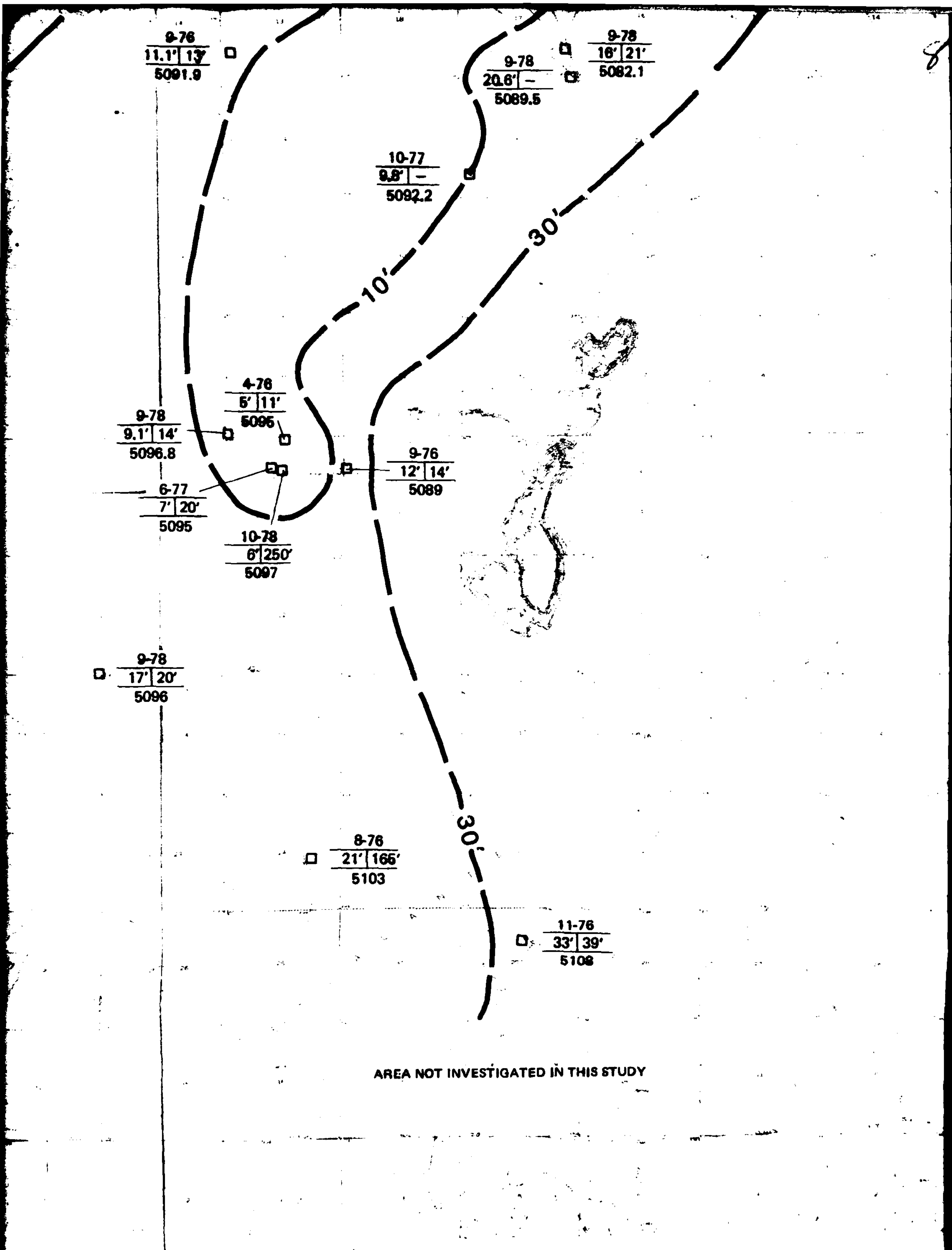


5
8-76
185' 230'
5170
B(O)-11
dry 101'
MARY'S HOLLOW
MAIN OPERATIONAL
BASE
150'
RUNWAY
50'
3-78
230' –
5140
3-78
180' 230'
5142
3-78
100' 150'
5138
8-76
64' 150'
5135
3-78
63' 100'
5145
YALE
CROSSING
100'
10-77
147' 240'
5128
3-78
39' 100'
5128
HEIST
10-72
198' 234'
5137
3-79
98' 130'
5129
10-73
188' 220'
5148
6-70
147' 185'
5138
4-72
224' 262'
5137
AREA NOT INVESTIGATED IN THIS STUDY

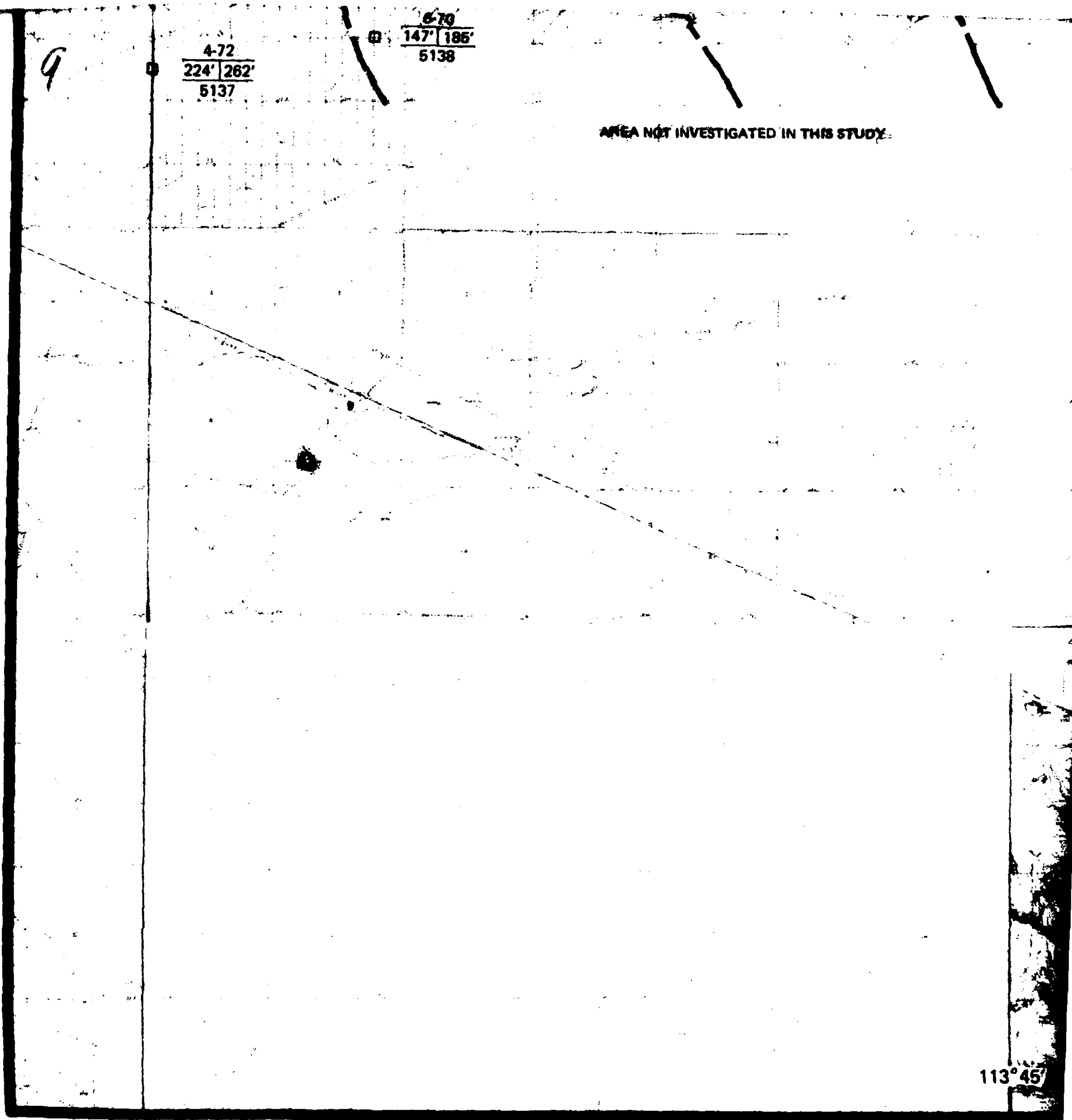


TED
MBLY
AREA
6
4-62
165' 185'
5138
9-76
87.6' 200'
5114.4
7-76
89.5' –
5116.6
9-76
87.6' 200'
5114.4
10-78
86.6' –
5108.4
100'
ZANE
9-63
62' 200'
5112
3-77
43.9' 58'
5119.1
5-75
54' 154'
5111.6
3-79
66.1' 150'
5133.9
3-77
62' 112'
5133
8-76
76' 86'
5132
3-78
24.3' –
5126.7
BERYL
9-73
16' 180'
5146
10-79
32.1' 253'
5101.9
1-75
31' 181'
5101
6-77
33' 100'
5130
3-79
27' 65'
5101
30'
3-77
19' 24'
5122
6-77
21' –
5117
3-78
17' 20'
5115
6-77
23' –
5115
6-77
25' 192'
5108
3-79
29' 230'
5107
6-77
26' 193'
5107
8-77
25' 30'
5102
8-76
26' –
5101
5-72
26' 170'
5121
11-74
37' 204'
5108
9-71
35' –
5115
9-74
21' 180'
5119
3-76
19' 186'
5123
11-74
37' 204'
5108
4-72
30' 192'
5116
3-79
34' 120'
5102


100'
ZANE
3-78
87' 141'
5113
9-63
200'
5112
10-79
32.1' 253'
5101.9
30'
9-76
11.1' 13'
5091.9
9-78
20.6' –
5089.5
10-77
9.8' –
5092.2
30'
10'
4-76
5' 11'
5095
9-78
9.1' 14'
5096.8
6-77
7' 20'
5095
9-76
12' 14'
5089
10-78
6' 250'
5097
9-78
17' 20'
5096
9-78
22' 24'
5101
9-78
17' –
5100
8-76
21' 165'
5103
30'
AREA NOT INVESTIGATED IN THIS STUDY
AREA NOT INVESTIGATED IN THI
EXPLA
WATER WEL

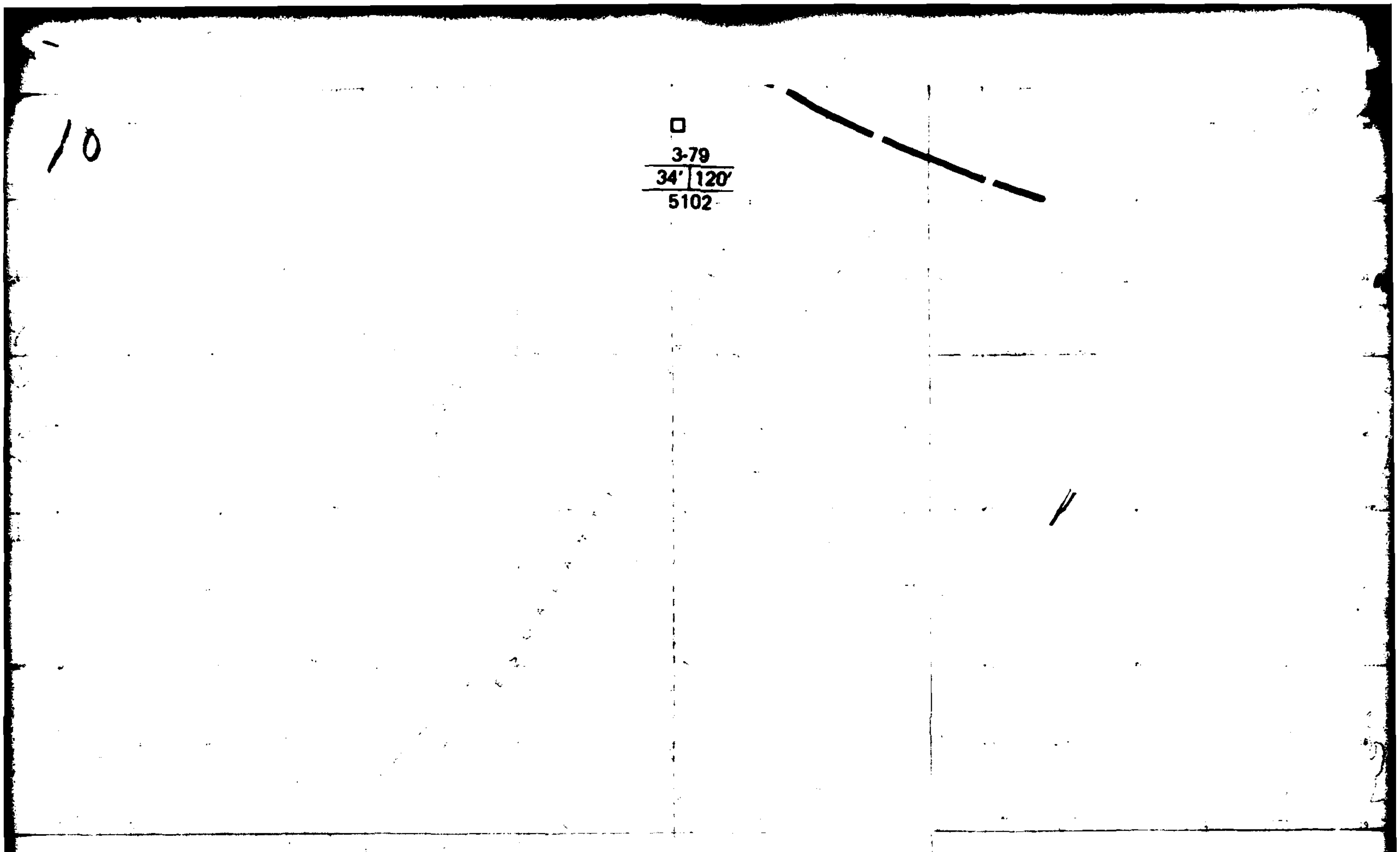


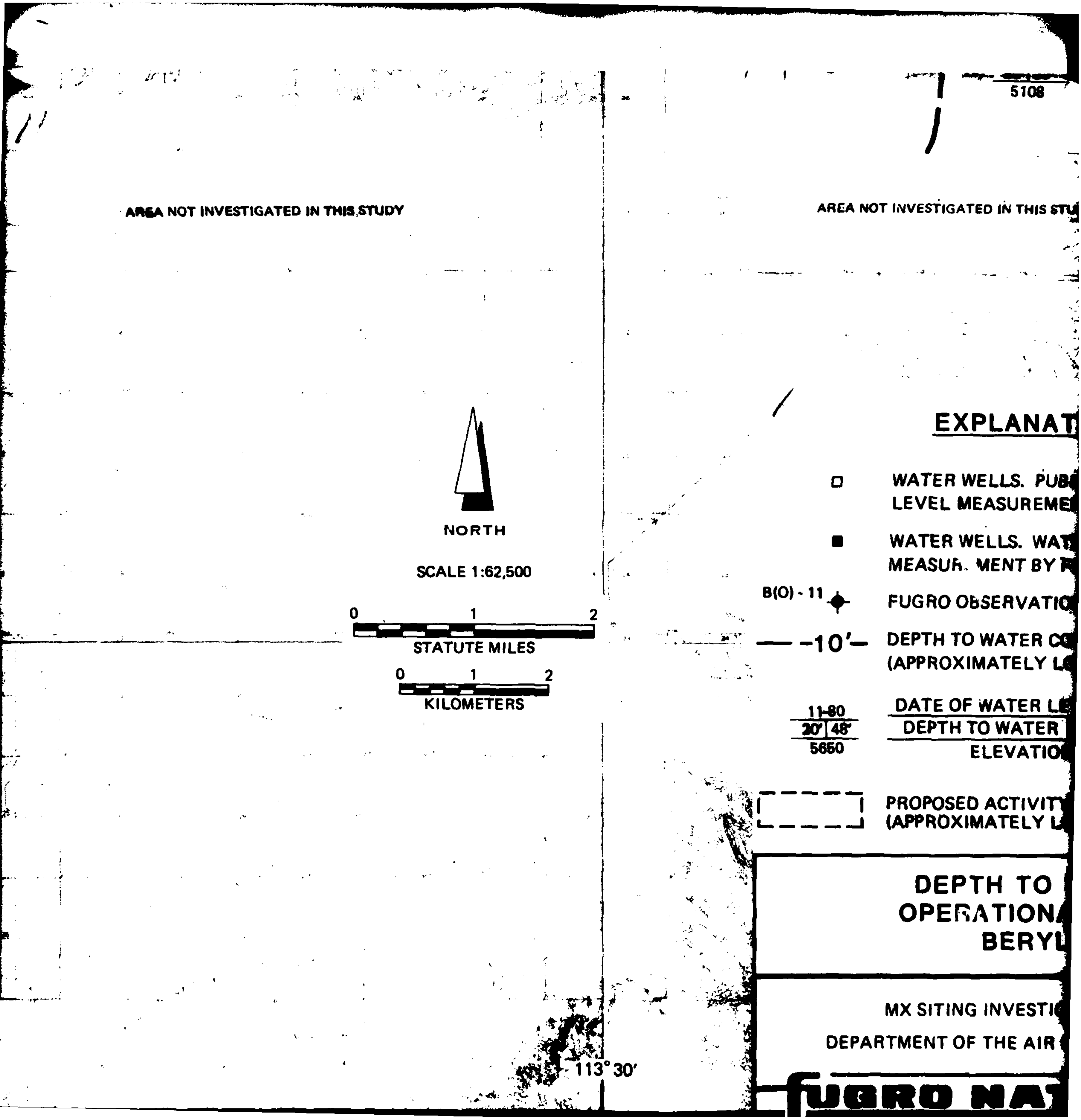
EXPLANATION


9
4-72
224' 262'
5137
6-70
147' 185'
5138
AREA NOT INVESTIGATED IN THIS STUDY
113°45'

5

20 MARCH 81


10
3-79
34' | 120'
5102



5108
AREA NOT INVESTIGATED IN THIS STUDY
AREA NOT INVESTIGATED IN THIS STU
NORTH
SCALE 1:62,500
0 1 2
STATUTE MILES
0 1 2
KILOMETERS
113° 30'
EXPLANAT
WATER WELLS. PUB
LEVEL MEASUREME
WATER WELLS. WAT
MEASUR. MENT BY F
B(O) - 11
FUGRO OBSERVATIO
-10'
DEPTH TO WATER CO
(APPROXIMATELY LO
11-80
20' | 48'
5650
DATE OF WATER LE
DEPTH TO WATER
ELEVATIO
PROPOSED ACTIVIT
(APPROXIMATELY L
DEPTH TO
OPERATION
BERYL
MX SITING INVESTI
DEPARTMENT OF THE AIR
FUGRO NAT

12

5108

AREA NOT INVESTIGATED IN THIS STUDY

TH

:62,500

2

MILES

2

TERS

113° 30'

EXPLANATION

□ WATER WELLS. PUBLISHED WATER LEVEL MEASUREMENT

■ WATER WELLS. WATER LEVEL MEASUREMENT BY FUGRO

B(O) - 11 ✦ FUGRO OBSERVATION WELLS

—— -10'— DEPTH TO WATER CONTOURS (APPROXIMATELY LOCATED)

11-80	DATE OF WATER LEVEL MEASUREMENT
20' | 48'	DEPTH TO WATER | DEPTH TO WELL
5650	ELEVATION OF WATER

PROPOSED ACTIVITY CENTER BOUNDARY (APPROXIMATELY LOCATED)

DEPTH TO WATER MAP
OPERATIONAL BASE SITE
BERYL, UTAH

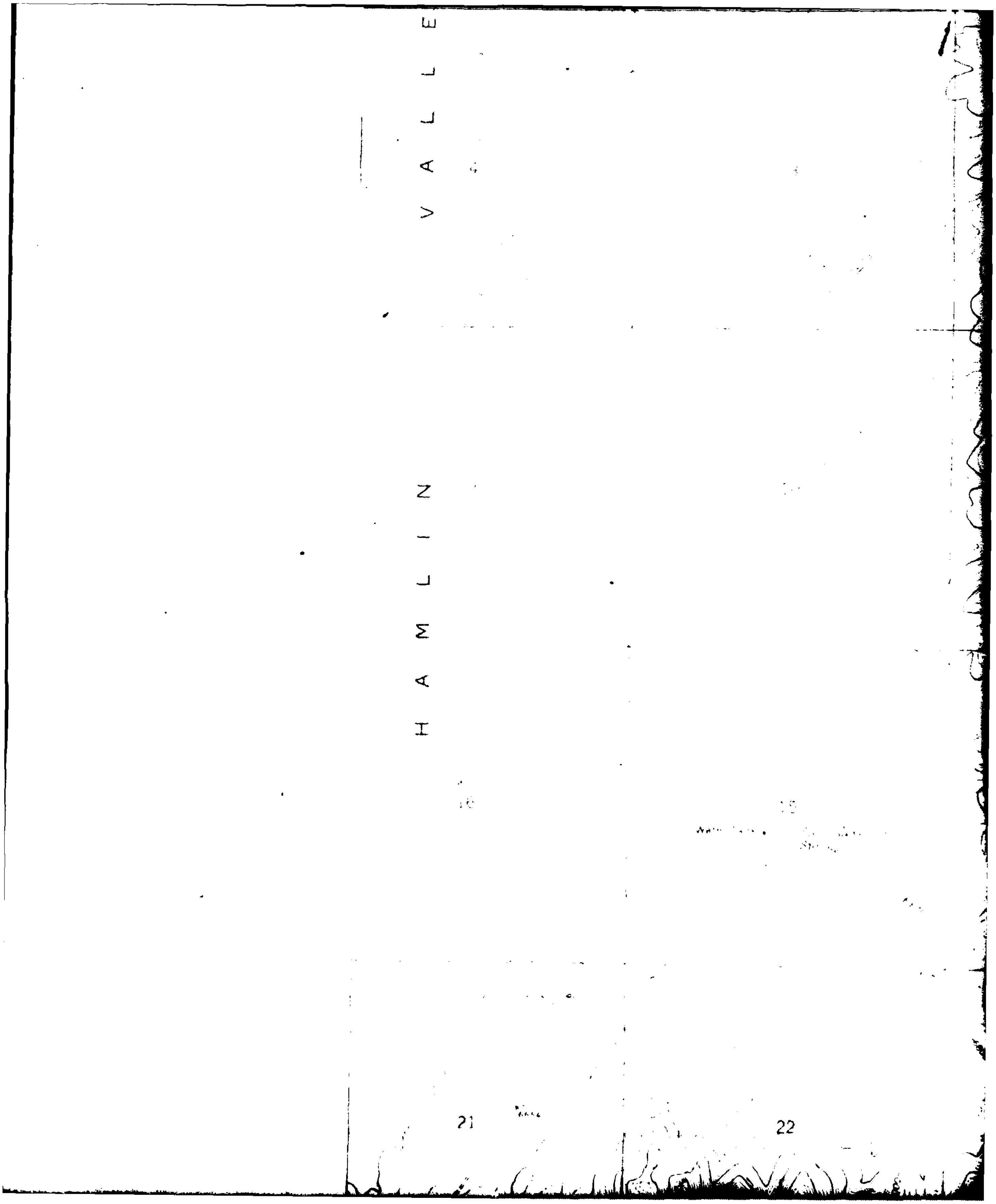
MX SITING INVESTIGATION

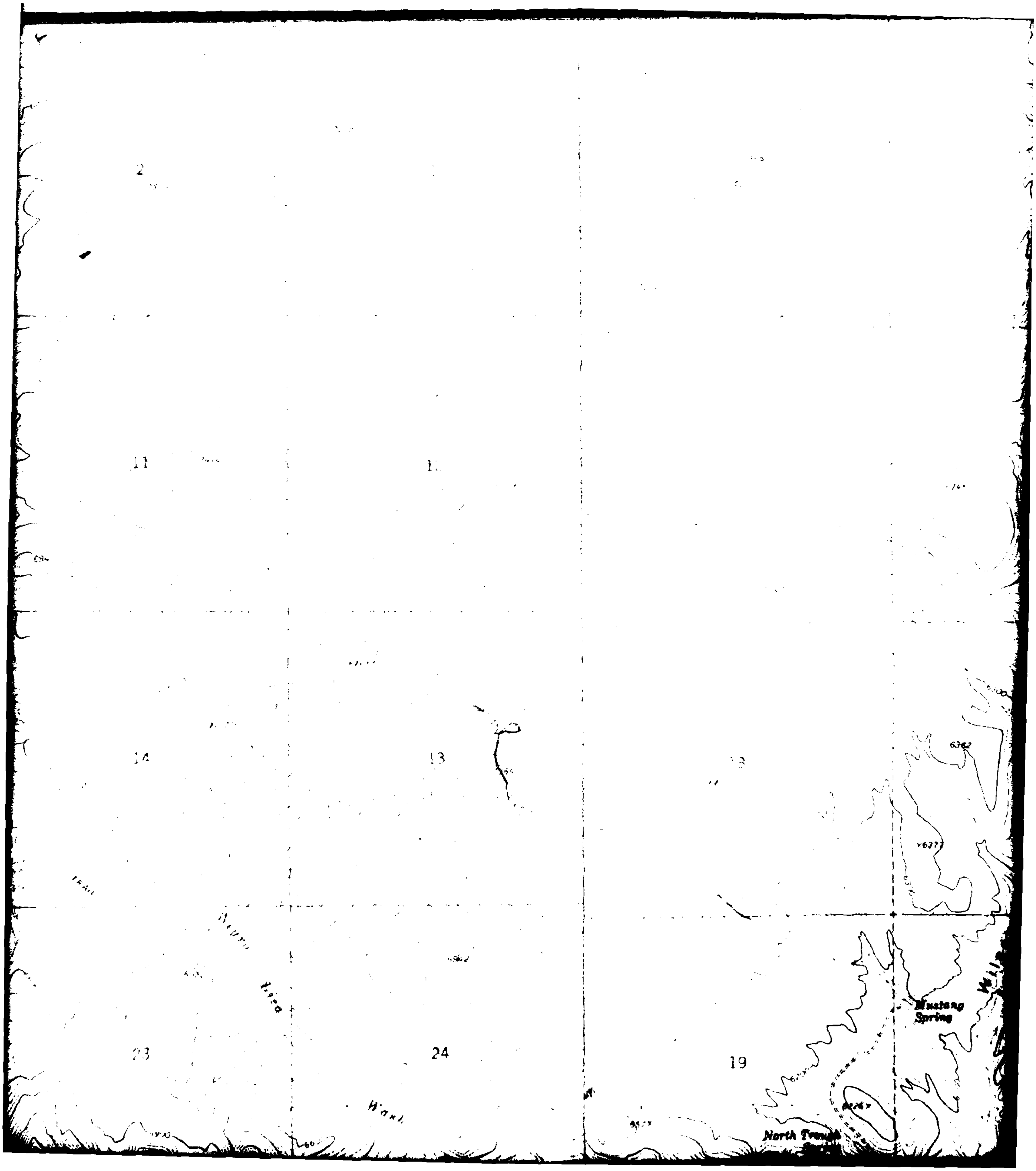
DEPARTMENT OF THE AIR FORCE – BMO

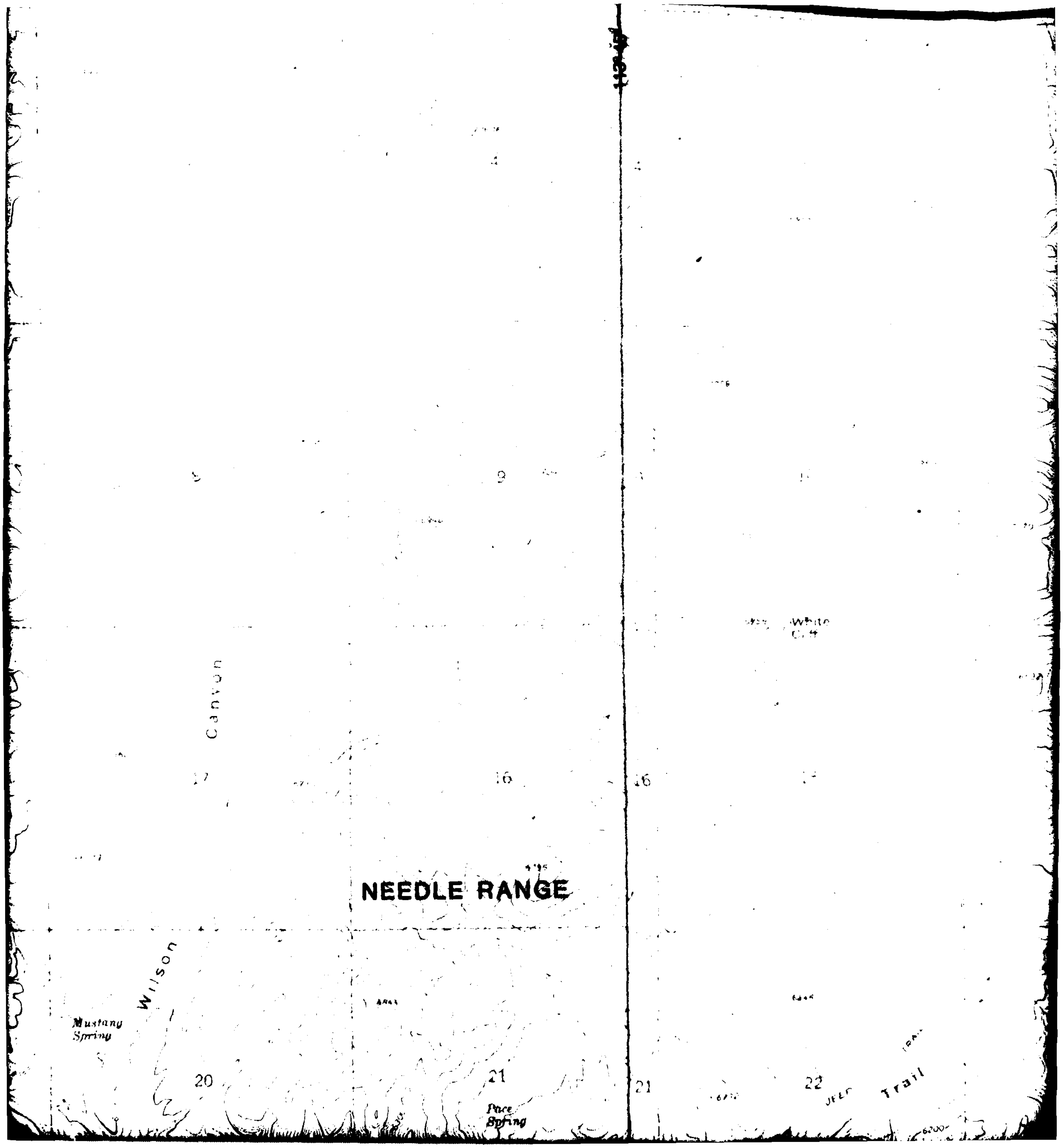
DRAWING

5-2

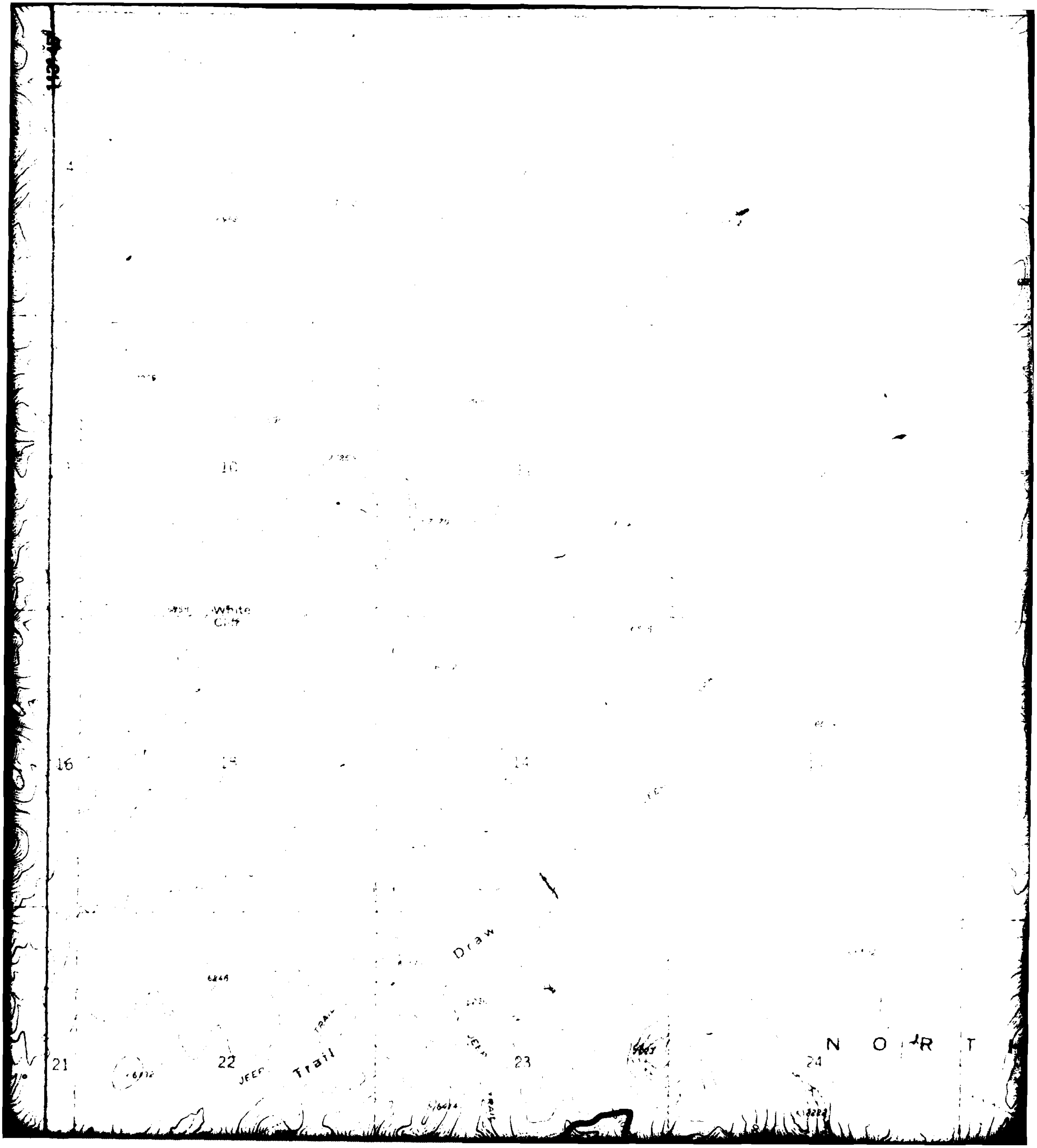
FUGRO NATIONAL, INC.


HAMLIN VALLEY
21
22

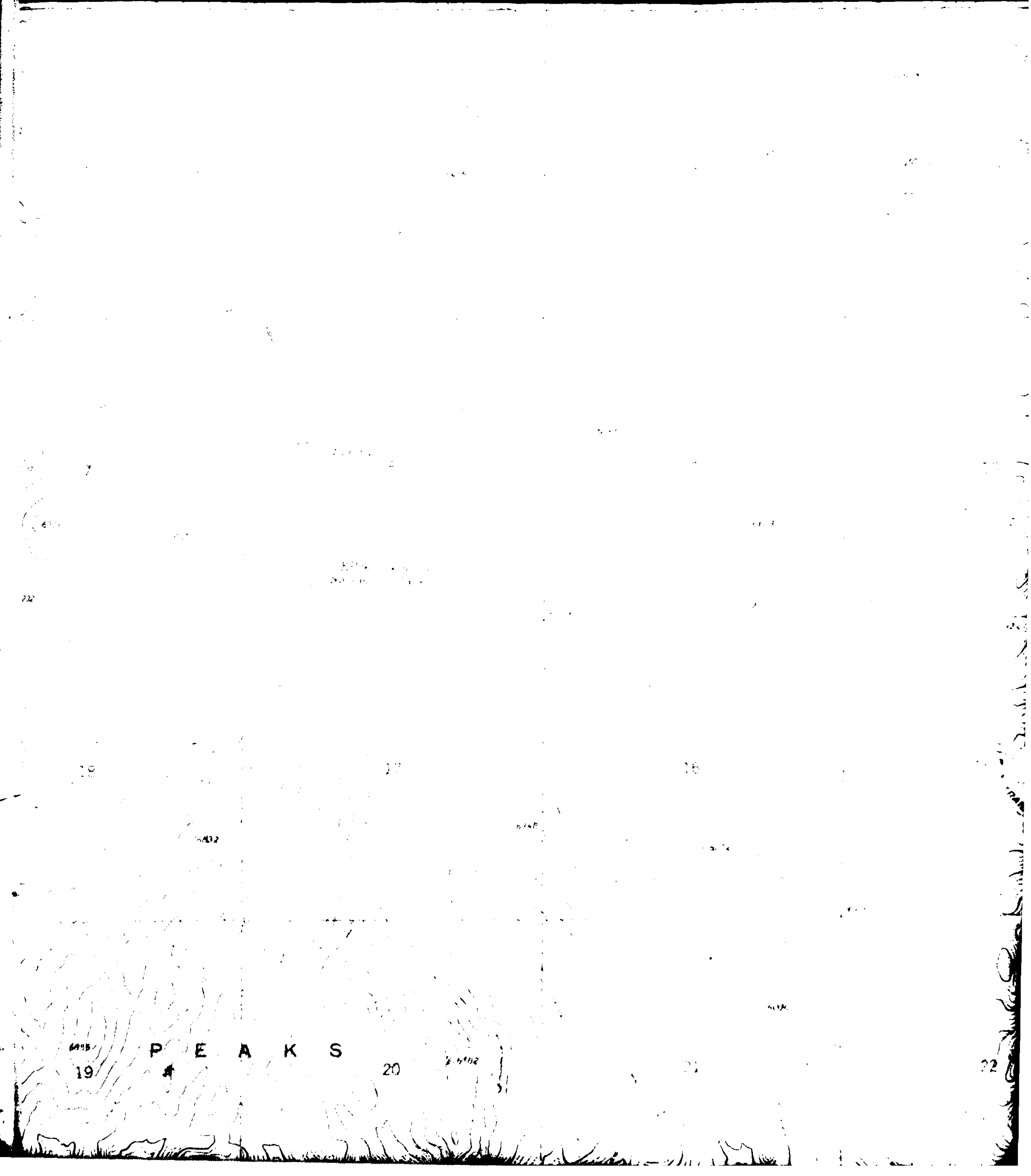

2
11
14
13
24
19
6362
Mustang
Spring

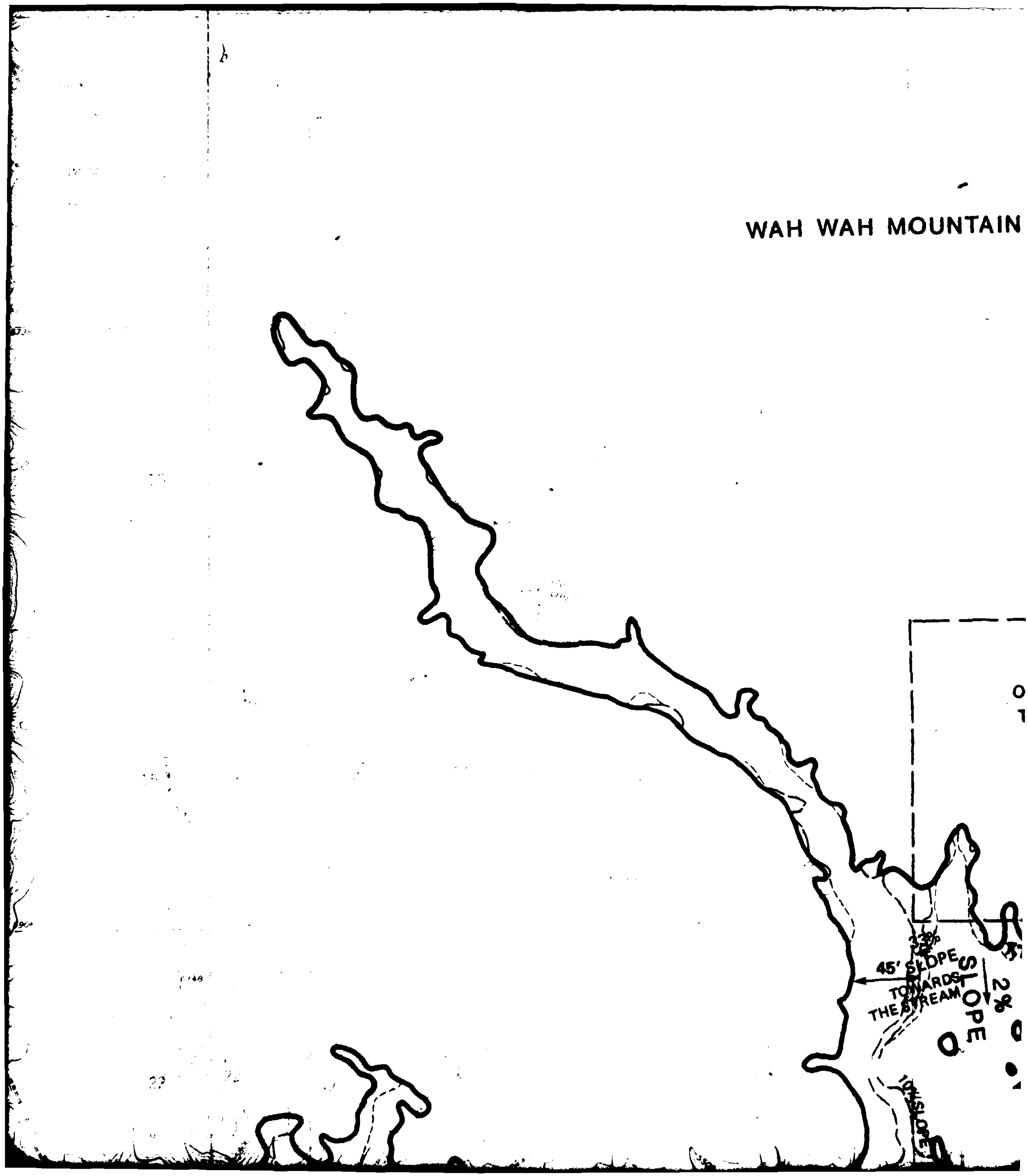


NEEDLE RANGE
Canyon
Wilson
Mustang Spring
Pace Spring
White Cliff
Trail
4
4
9
16
16
17
20
21
21
22

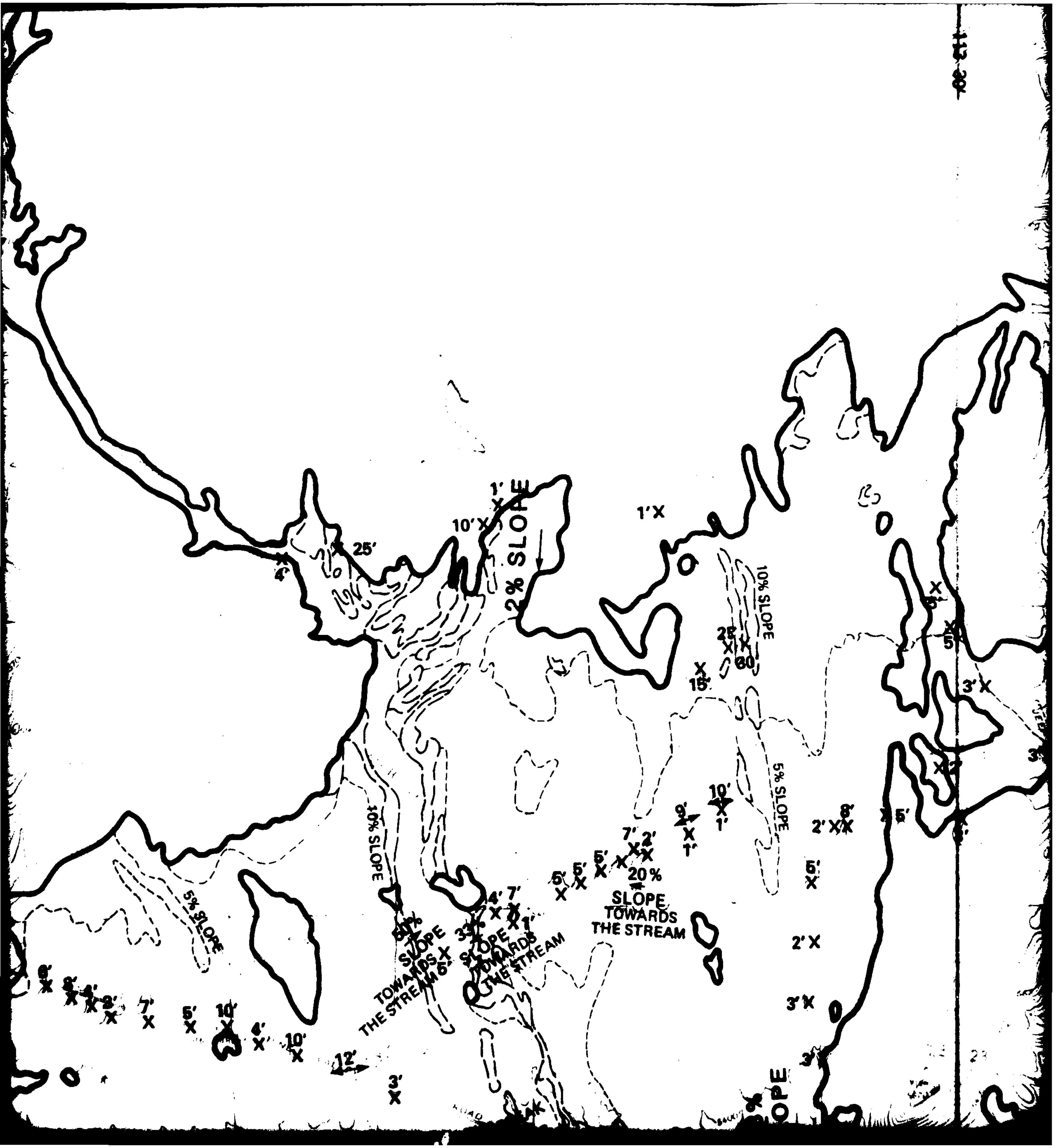

4
10
White Cliff
16
Draw
6848
21
22
JEEP
Trail
23
24
N O R T

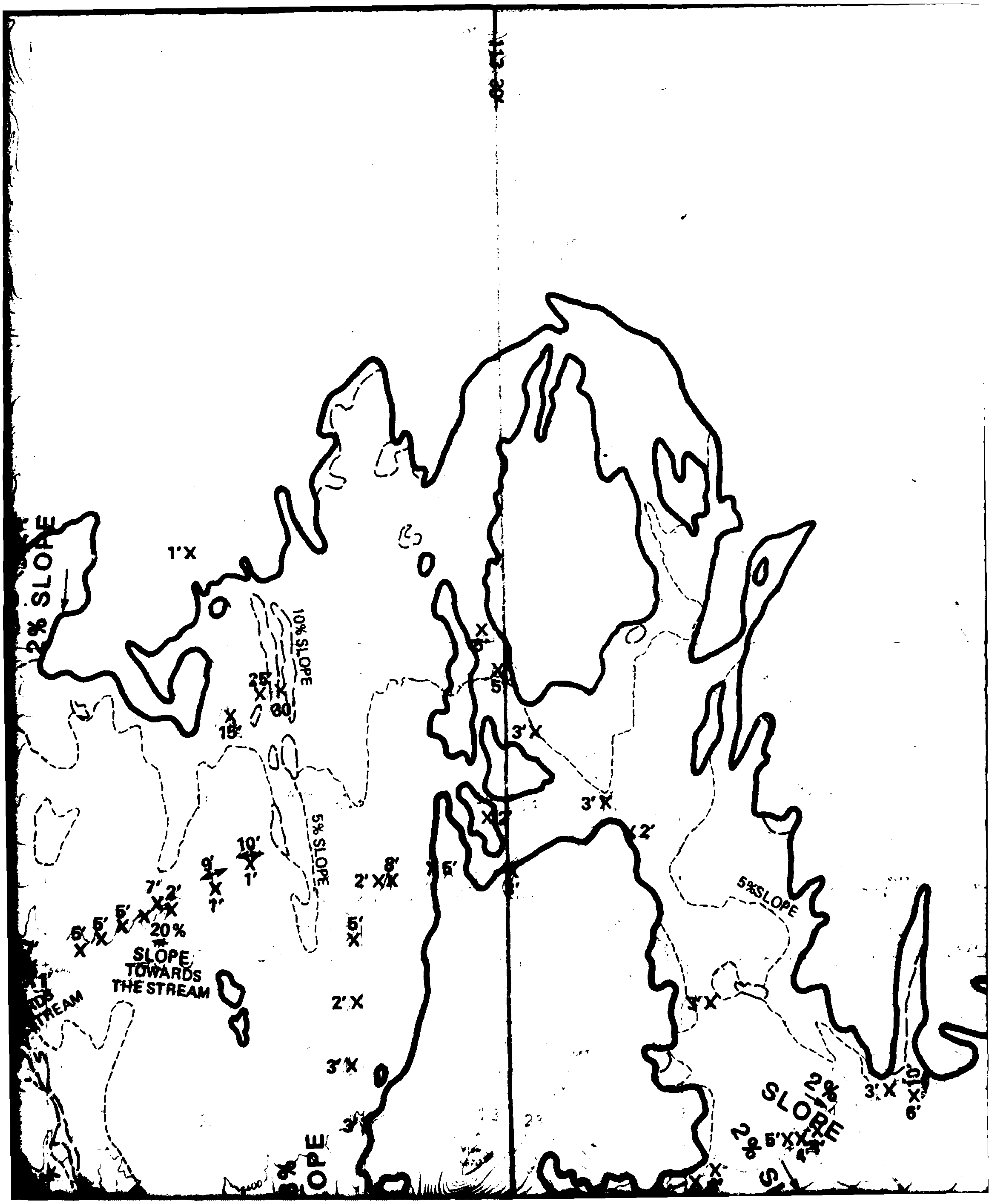
15



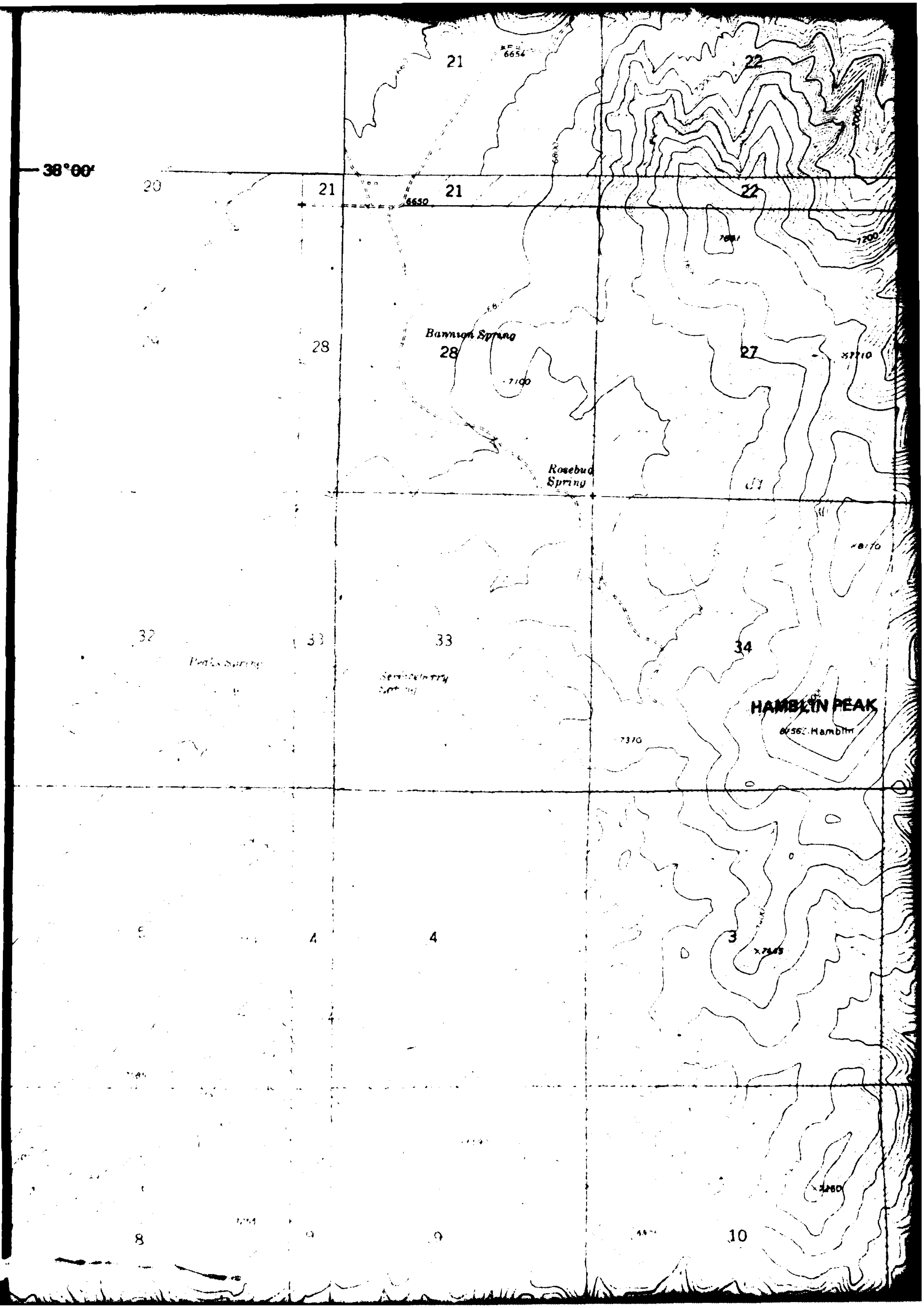


WAH WAH MOUNTAIN
33%
45' SLOPE
TOWARDS
THE STREAM
SLOPE
2%
10% SLOPE

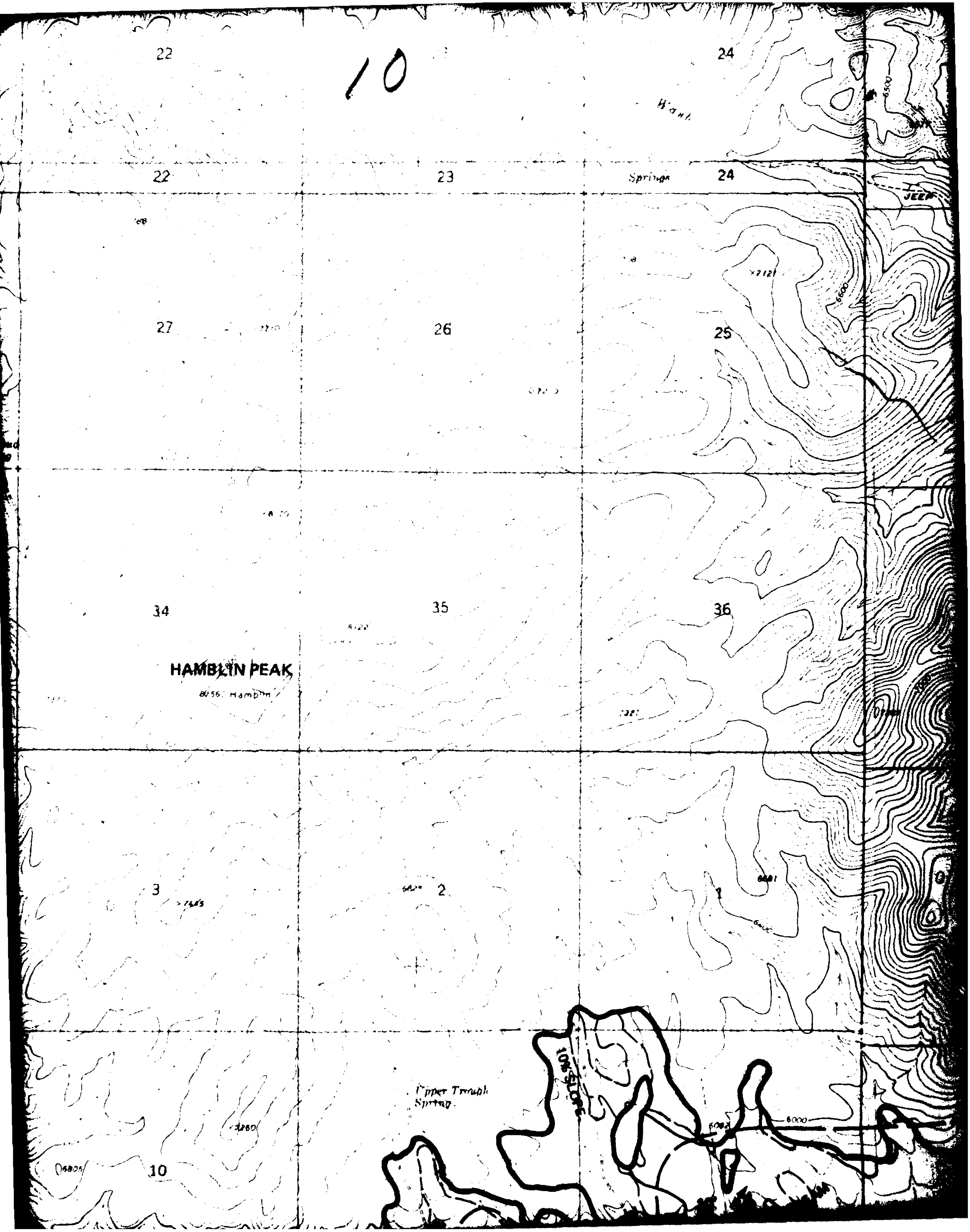

2% SLOPE
10% SLOPE
5% SLOPE
10% SLOPE
5% SLOPE
20 %
SLOPE
TOWARDS
THE STREAM
SLOPE
TOWARDS
THE STREAM
SLOPE
TOWARDS
THE STREAM
25'
1'X
2'X
3'X
12'
3'
10'
4'
5'
7'


2% SLOPE
1' X
10% SLOPE
25' X
X 30
X 15'
5% SLOPE
10'
9'
1'
8'
2' X X
5'
7' 2'
20%
SLOPE TOWARDS THE STREAM
2' X
3' X
3' X
3' X
3' X
2'
5%SLOPE
3' X
SLOPE
2%
3' X
6'
5' X

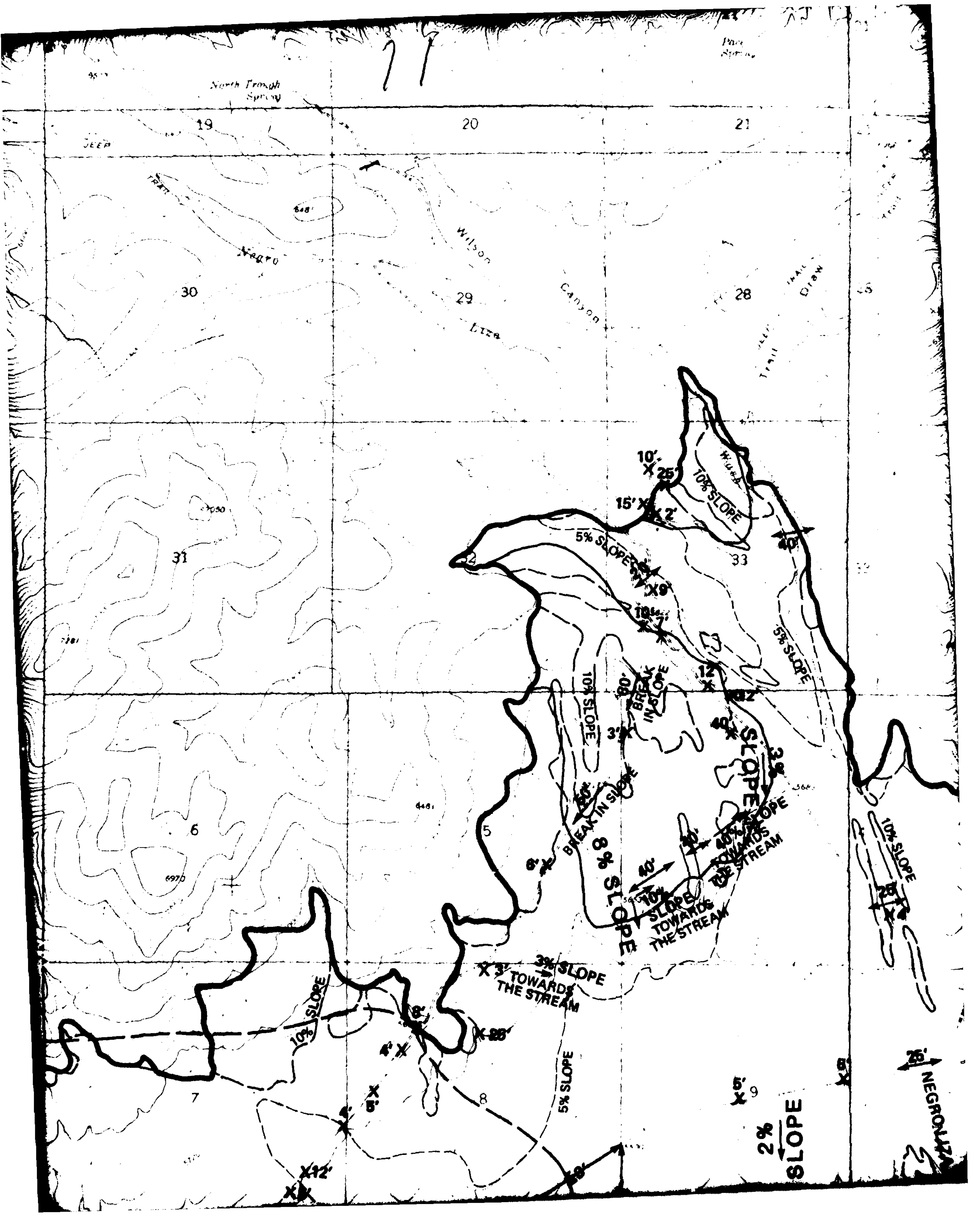
9

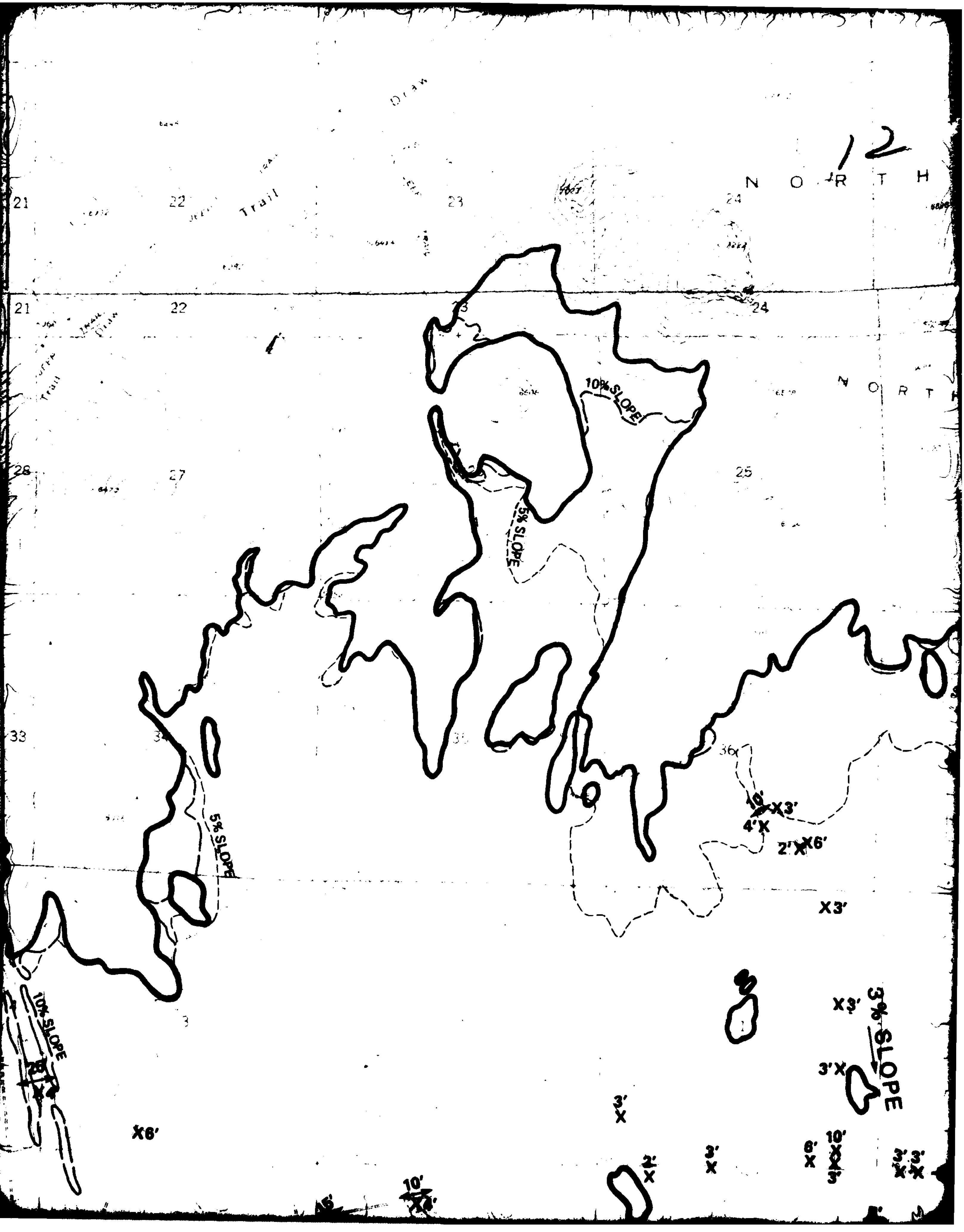


38°00′
21
22
20
21
21
22
6650
Bannion Spring
28
28
27
7100
Rosebud
Spring
32
33
33
34
HAMBLIN PEAK
Hamblin
7370
4
4
3
8
10



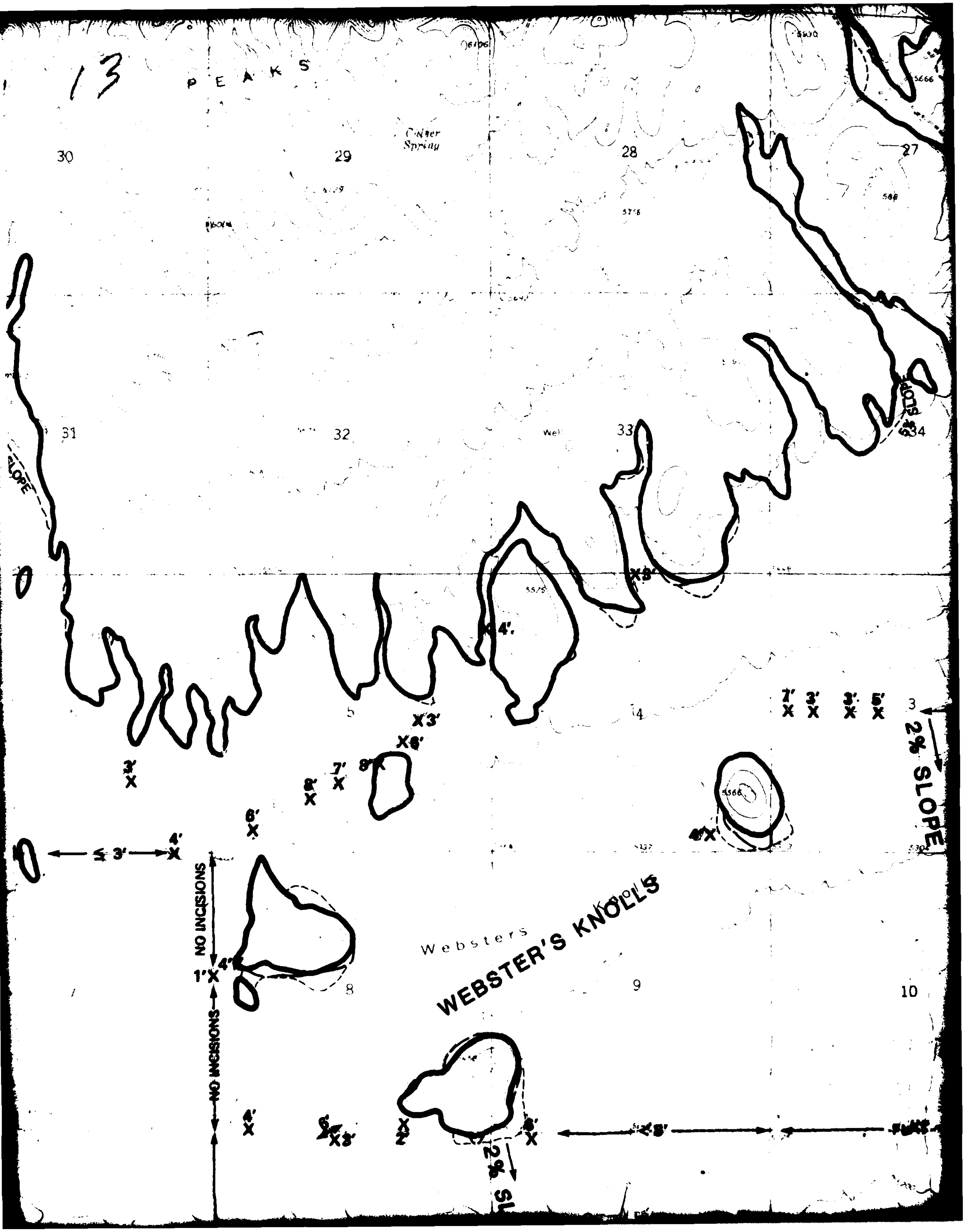
10
22
24
23
Springs
JEEP
27
26
25
34
35
36
HAMBLIN PEAK
3
2
1
10% SLOPE
Upper Trough Spring
6000
10

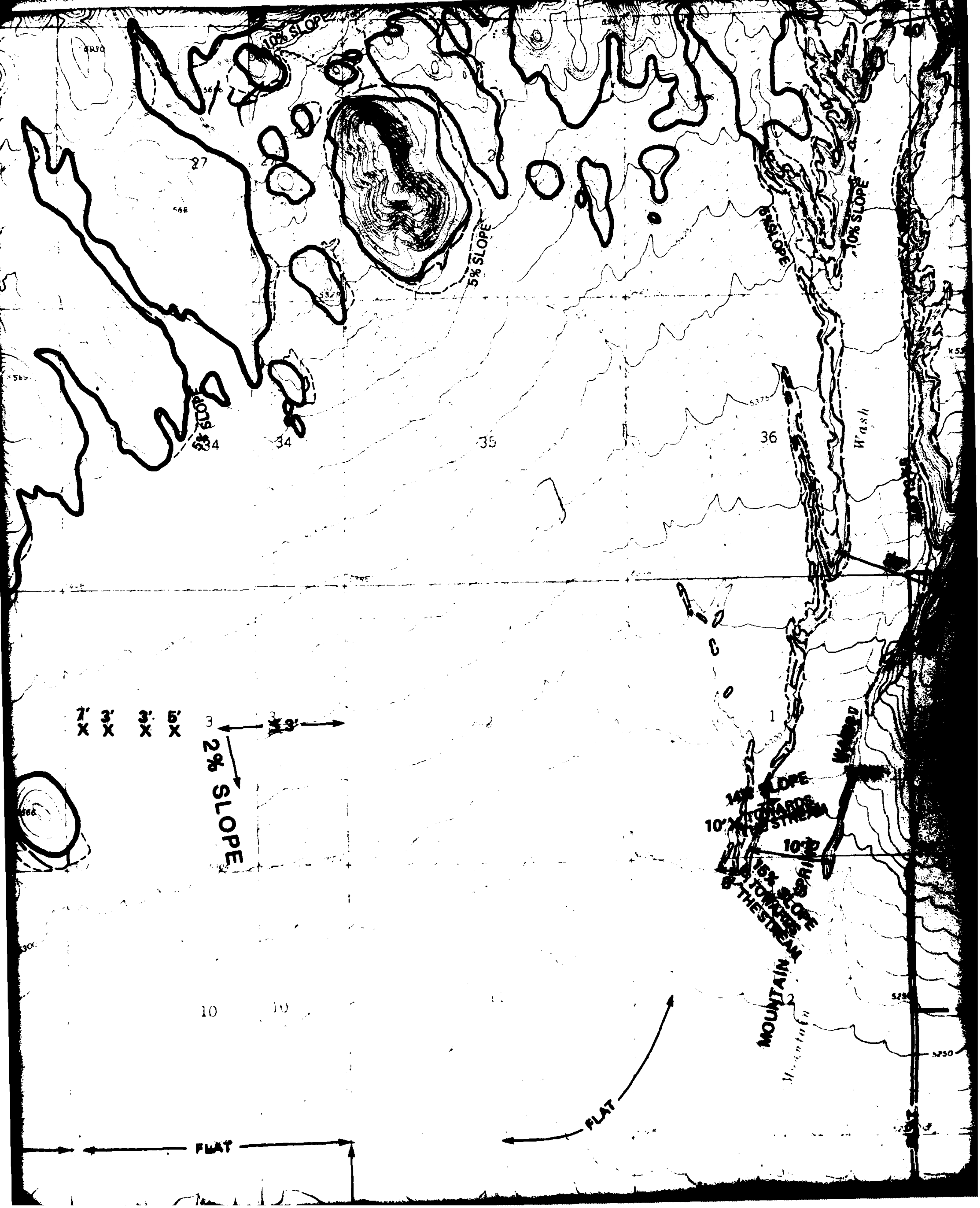

North Trough Spring
19
20
21
JEEP
TRAIL
Negro
Wilson
Canyon
Liza
Draw
Trail
30
29
28
31
33
6
5
7
8
9
10% SLOPE
5% SLOPE
10' X
25'
15' X
2'
40'
X9
12
X
10% SLOPE
8' BREAK IN SLOPE
3' X
40'
SLOPE
BREAK IN SLOPE
8% SLOPE
6'
40'
10% SLOPE TOWARDS THE STREAM
40% SLOPE TOWARDS THE STREAM
10% SLOPE
X 3'
3% SLOPE TOWARDS THE STREAM
10% SLOPE
X 26'
4'
5% SLOPE
5'
X12'
5' X
2% SLOPE
25'
NEGRO LIZA

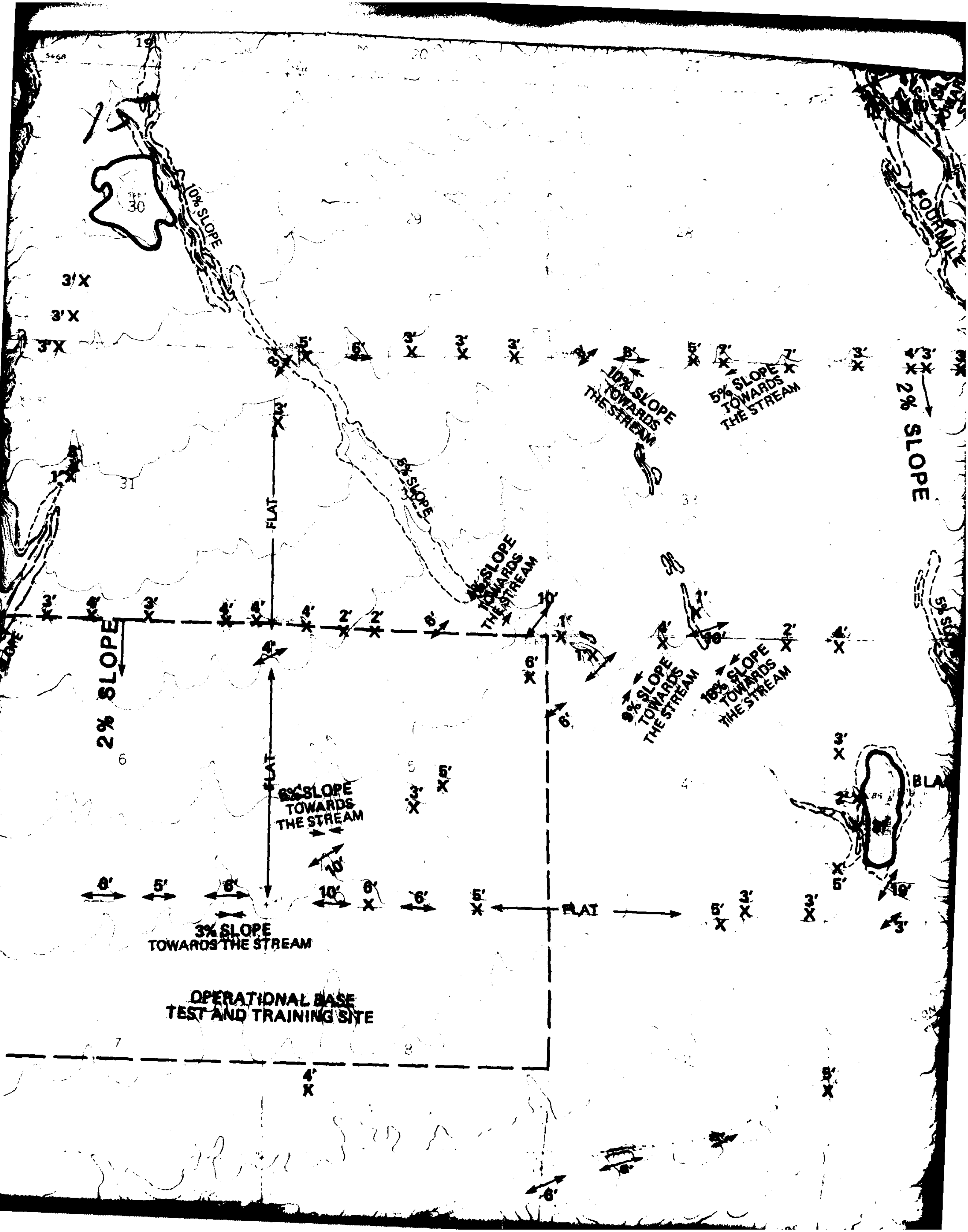


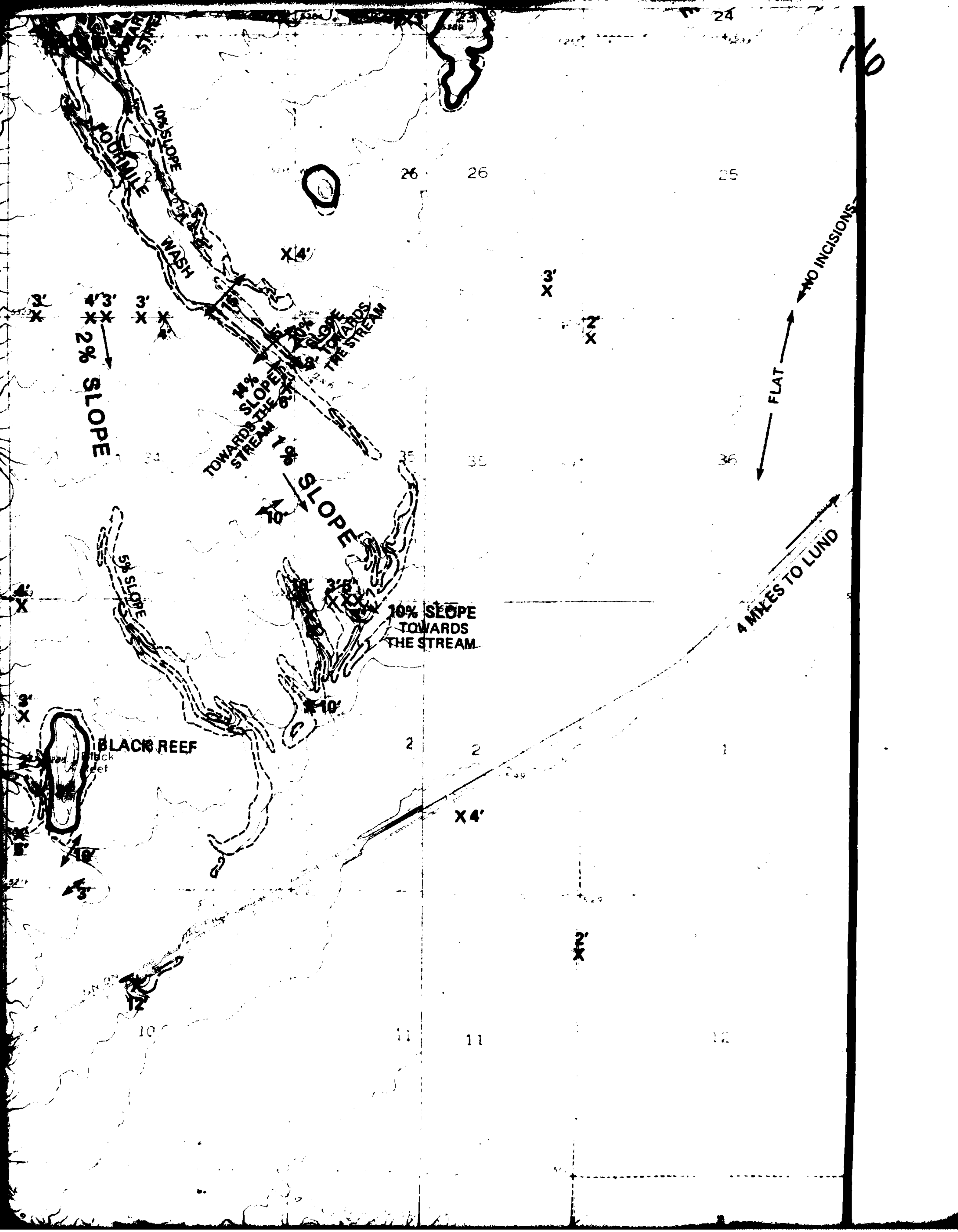
12
NORTH
Trail
21
22
23
24
28
27
25
33
36
10% SLOPE
5% SLOPE
5% SLOPE
10% SLOPE
3% SLOPE
10' X3'
4'X
2'X X6'
X3'
X3'
3'X
3' X
X6'
2' X
3' X
6' X
10' X 3'
3' 3' X X
10' X6'

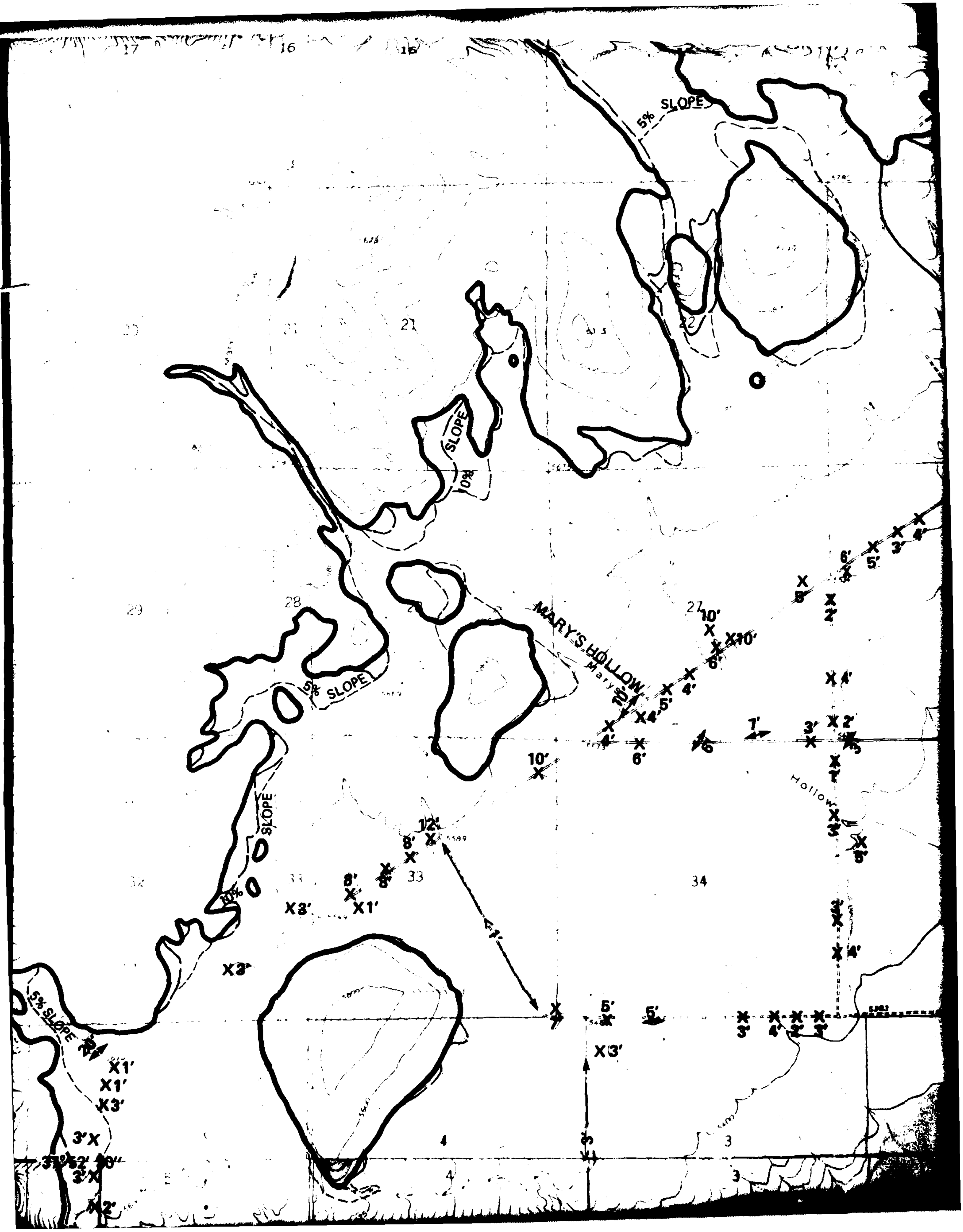
13

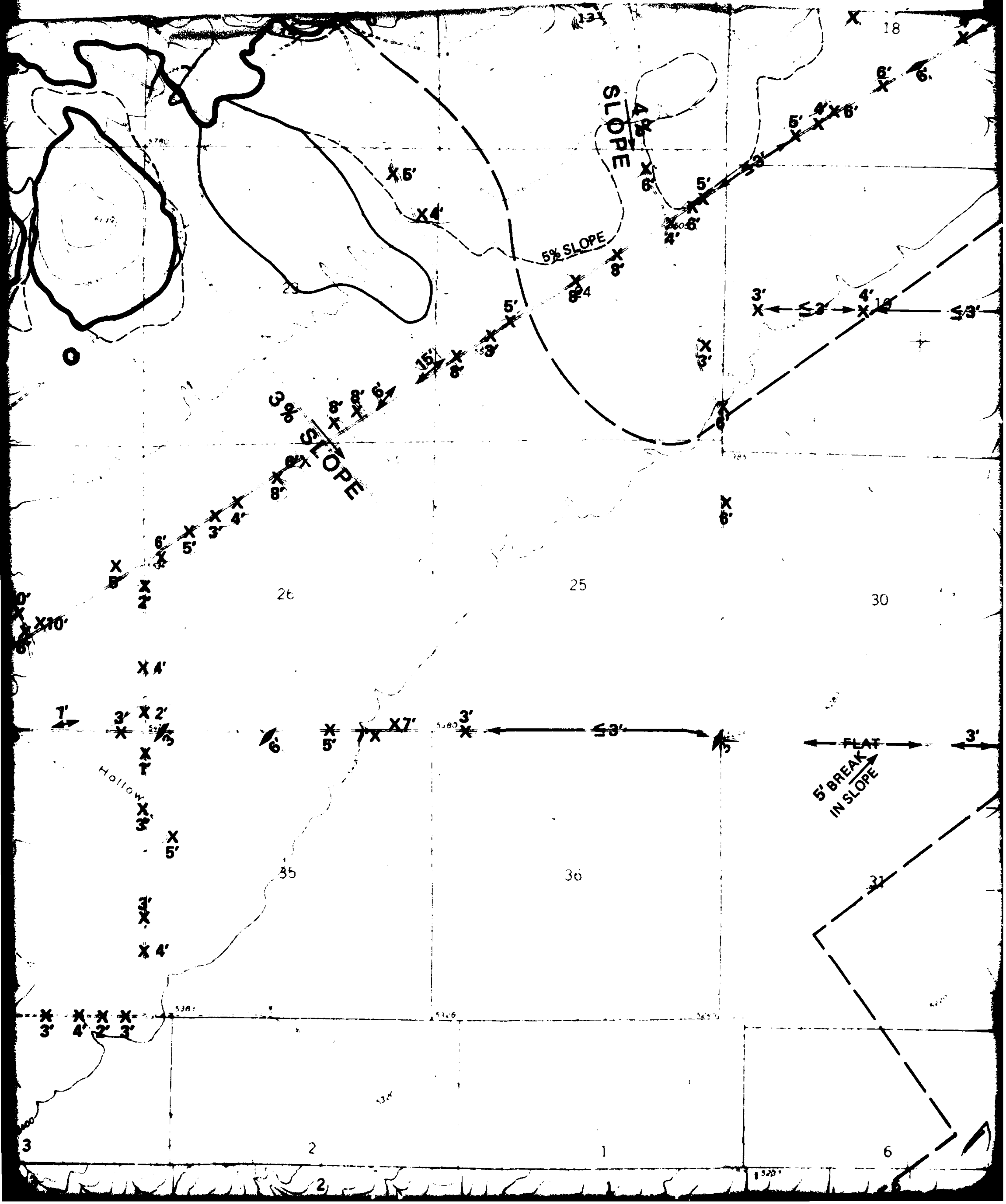

PEAKS
Cinder Spring
30
29
28
27
31
32
33
34
5
4
3
8
9
10
Well
SLOPE
X5'
X4'
X3'
X6'
8'X
7' X
6' X
3' X
6' X
4' X
≤ 3'
NO INCISIONS
4'
1'X
4' X
2% SLOPE
4'X
7' X
3' X
3' X
5' X
Websters
WEBSTER'S KNOLLS
X3'
X 2'
6' X
≤ 3'
2% SL


10% SLOPE
27
5% SLOPE
5% SLOPE
10% SLOPE
34
34
35
36
Wash
7'
X
3'
X
3'
X
5'
X
3'
2% SLOPE
1
2
14% SLOPE
TOWARDS THE STREAM
10'
15% SLOPE TOWARDS THE STREAM
MOUNTAIN SPRING
10
10
FLAT
FLAT

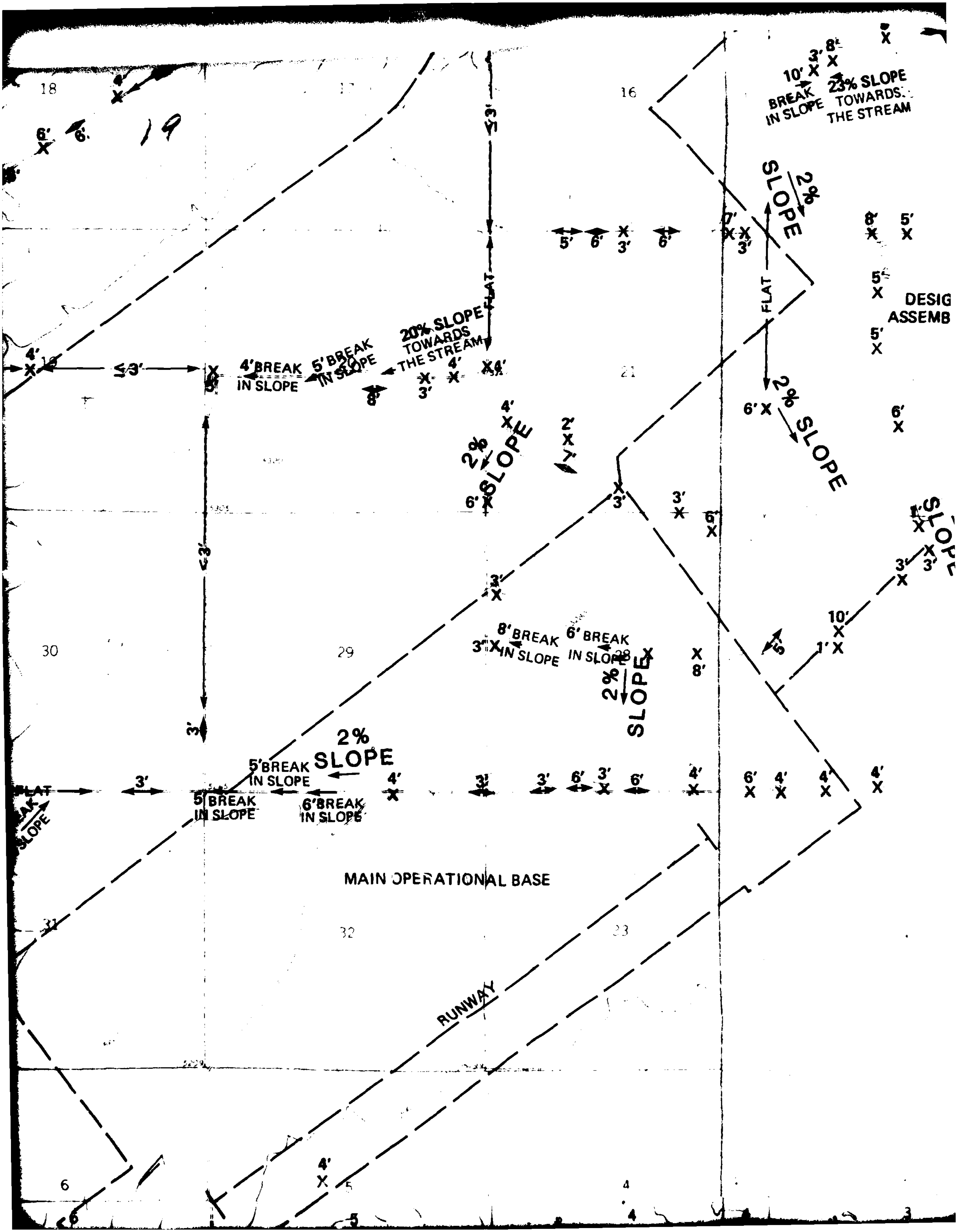

10% SLOPE
5% SLOPE
10% SLOPE TOWARDS THE STREAM
5% SLOPE TOWARDS THE STREAM
2% SLOPE
FLAT
TOWARDS THE STREAM
9% SLOPE TOWARDS THE STREAM
2% SLOPE
TOWARDS THE STREAM
FLAT
3% SLOPE TOWARDS THE STREAM
FOURMILE
OPERATIONAL BASE TEST AND TRAINING SITE


FOURMILE WASH
10% SLOPE
X 4'
3' X
2' X
3' X
4' X
3' X
3' X
15'
2% SLOPE
10% SLOPE TOWARDS THE STREAM
14% SLOPE TOWARDS THE STREAM
1% SLOPE
10
5% SLOPE
10'
3'
5'
10% SLOPE TOWARDS THE STREAM
10'
BLACK REEF
4' X
3' X
10
3
12
X 4'
2' X
NO INCISIONS
FLAT
4 MILES TO LUND
24
26
26
25
35
35
36
2
2
1
11
11
12
10

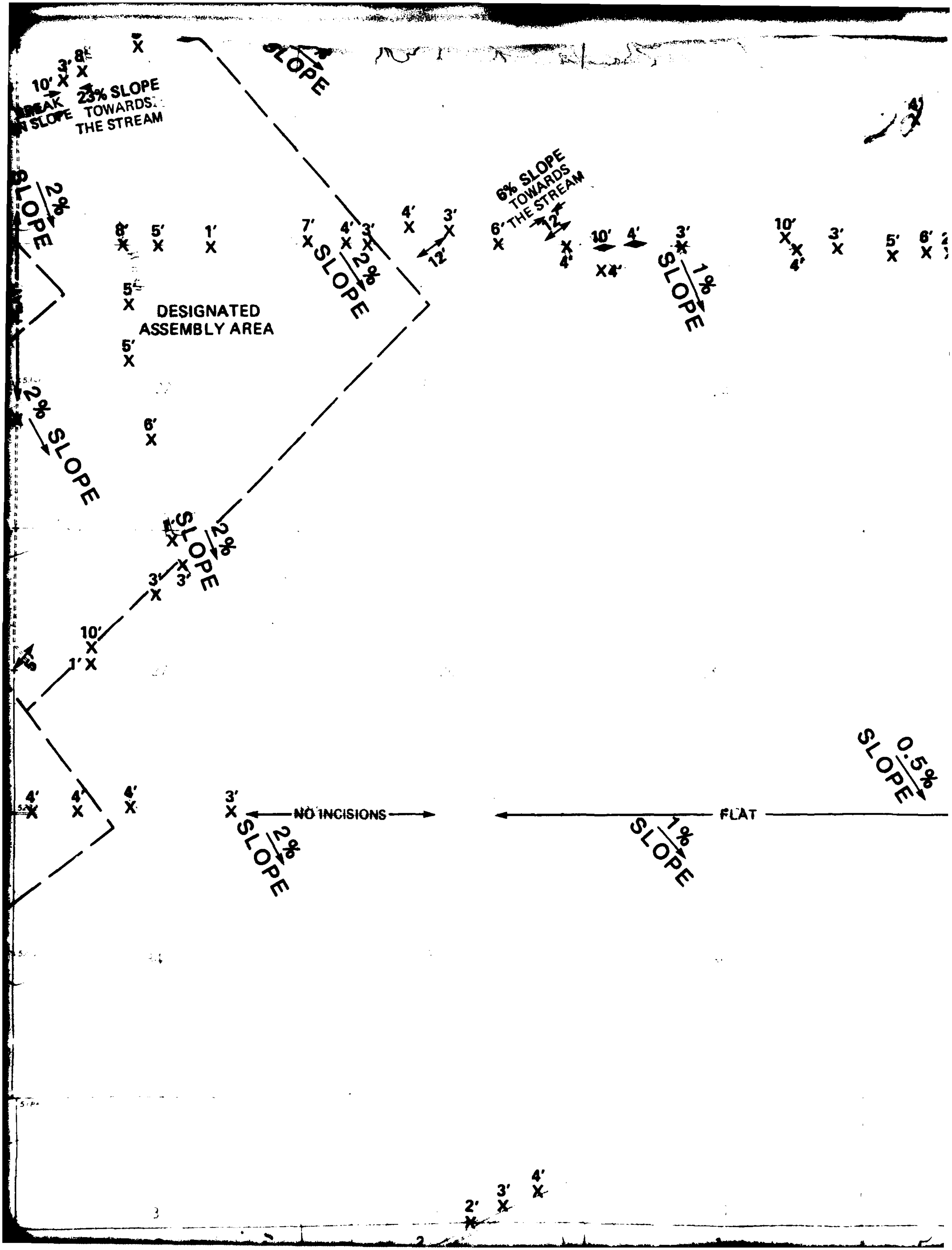

17
16
16
5% SLOPE
21
22
SLOPE
10%
28
29
27
MARY'S HOLLOW
Mary's
Hollow
5% SLOPE
SLOPE
10%
33
34
10'
X10'
6'
4'
5'
10'
X4'
4'
6'
1'
3'
X 2'
X 4'
6'
5'
3'
4'
X 2'
12'
8'
8'
8'
X3'
X1'
X3'
X 3'
5'
5'
3'
4'
2'
3'
4'
X3'
X1'
X1'
X3'
3'X
3'X
X2'
5% SLOPE
4
4
3
3



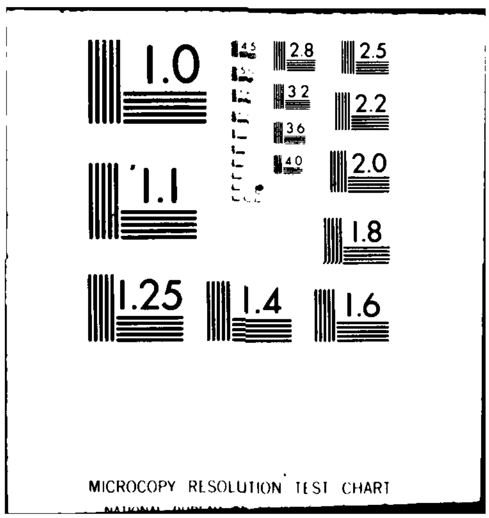
4% SLOPE
5% SLOPE
3% SLOPE
≤3'
FLAT
5' BREAK IN SLOPE
Hollow
18
23
24
19
26
25
30
35
36
31
2
1
6
3

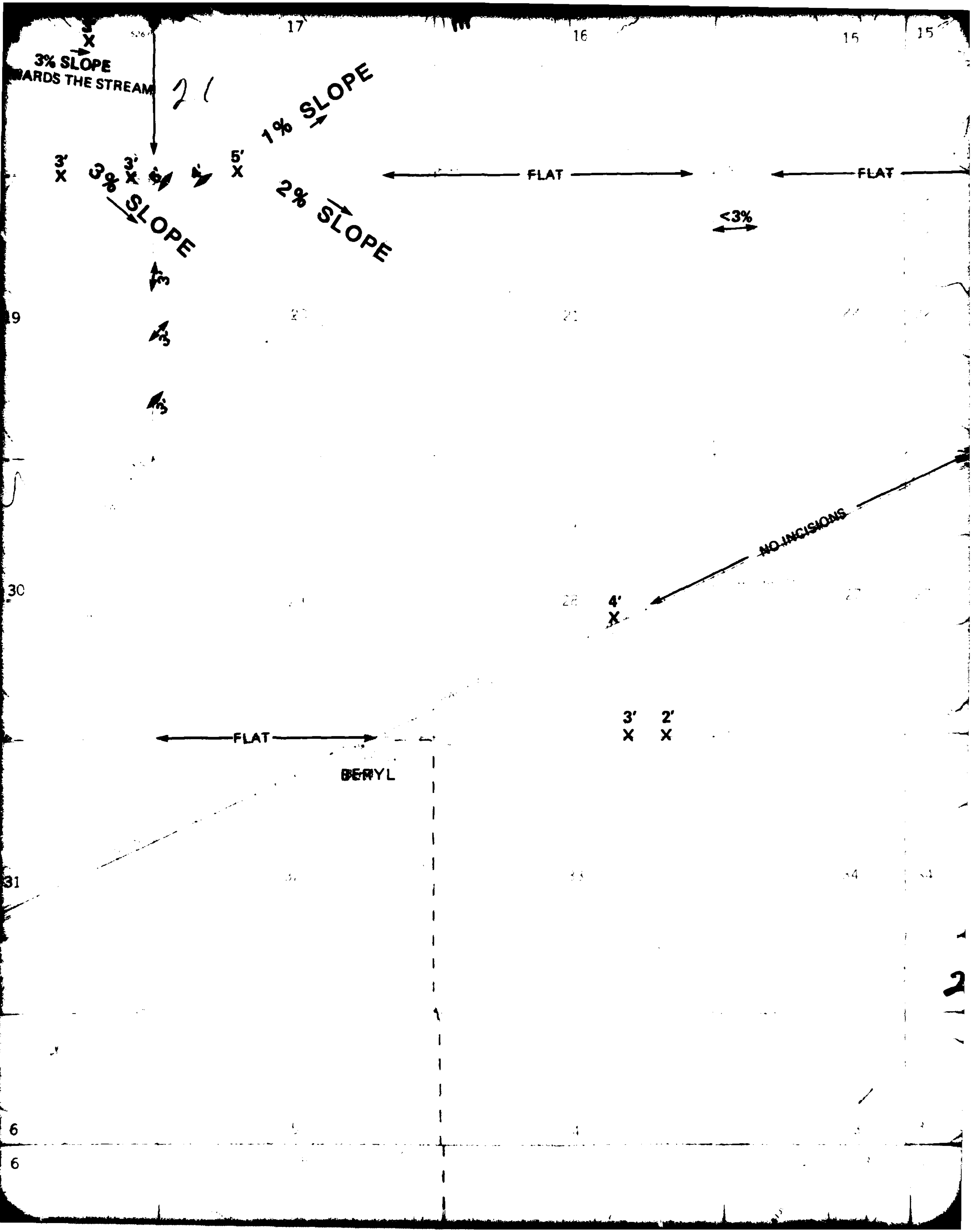


18
17
16
19
10' BREAK IN SLOPE
23% SLOPE TOWARDS THE STREAM
2% SLOPE
FLAT
20% SLOPE TOWARDS THE STREAM
5' BREAK IN SLOPE
4' BREAK IN SLOPE
20
21
DESIG
ASSEMB
2% SLOPE
2% SLOPE
30
29
8' BREAK IN SLOPE
6' BREAK IN SLOPE
28
2% SLOPE
2% SLOPE
5' BREAK IN SLOPE
5' BREAK IN SLOPE
6' BREAK IN SLOPE
FLAT
MAIN OPERATIONAL BASE
31
32
33
RUNWAY
6
5
4
3

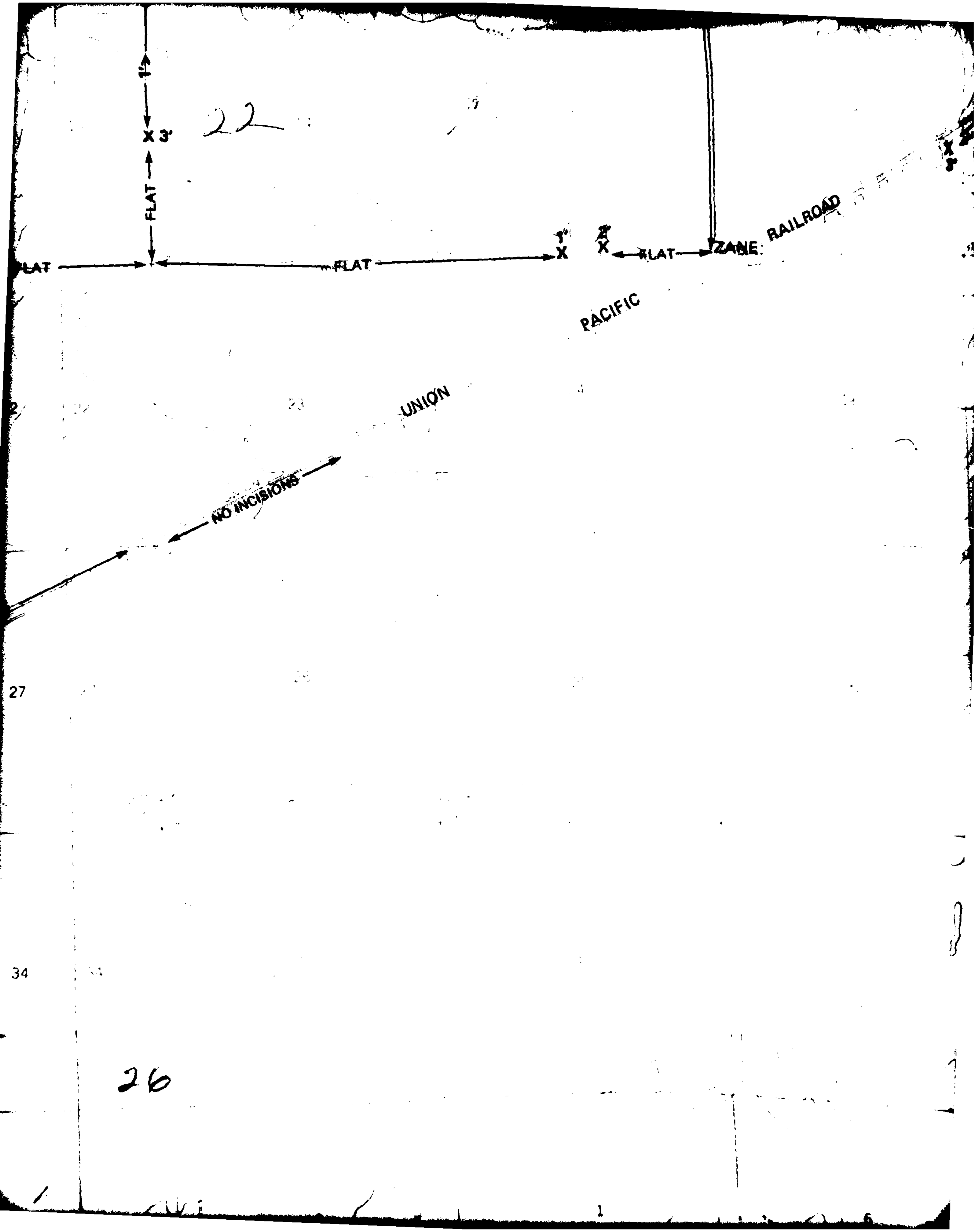


SLOPE
10'
3'
8'
23% SLOPE
TOWARDS
THE STREAM
2% SLOPE
8'
5'
1'
7'
4'
3'
2% SLOPE
4'
3'
12'
6% SLOPE
TOWARDS
THE STREAM
6'
12'
4'
10'
4'
3'
1% SLOPE
10'
3'
5'
6'
DESIGNATED
ASSEMBLY AREA
5'
5'
2% SLOPE
6'
2% SLOPE
3'
3'
10'
1'
4'
4'
4'
3'
NO INCISIONS
2% SLOPE
FLAT
1% SLOPE
0.5% SLOPE
4'
3'
2'


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
MICROCOPY RESOLUTION TEST CHART



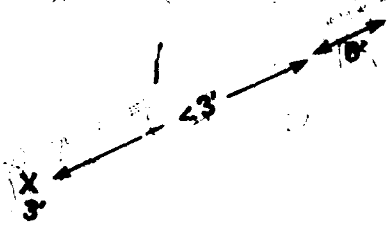
17
16
15
15
3% SLOPE
ARDS THE STREAM
21
1% SLOPE
3'
3'
5'
FLAT
FLAT
3% SLOPE
2% SLOPE
<3%
19
NO INCISIONS
30
4'
3'
2'
FLAT
BERYL
31
6
6


22
1'
X 3'
FLAT
FLAT
FLAT
1'
X
2'
X
FLAT
ZANE
UNION PACIFIC RAILROAD
NO INCISIONS
X
3'
2
27
34
26
1
6

1

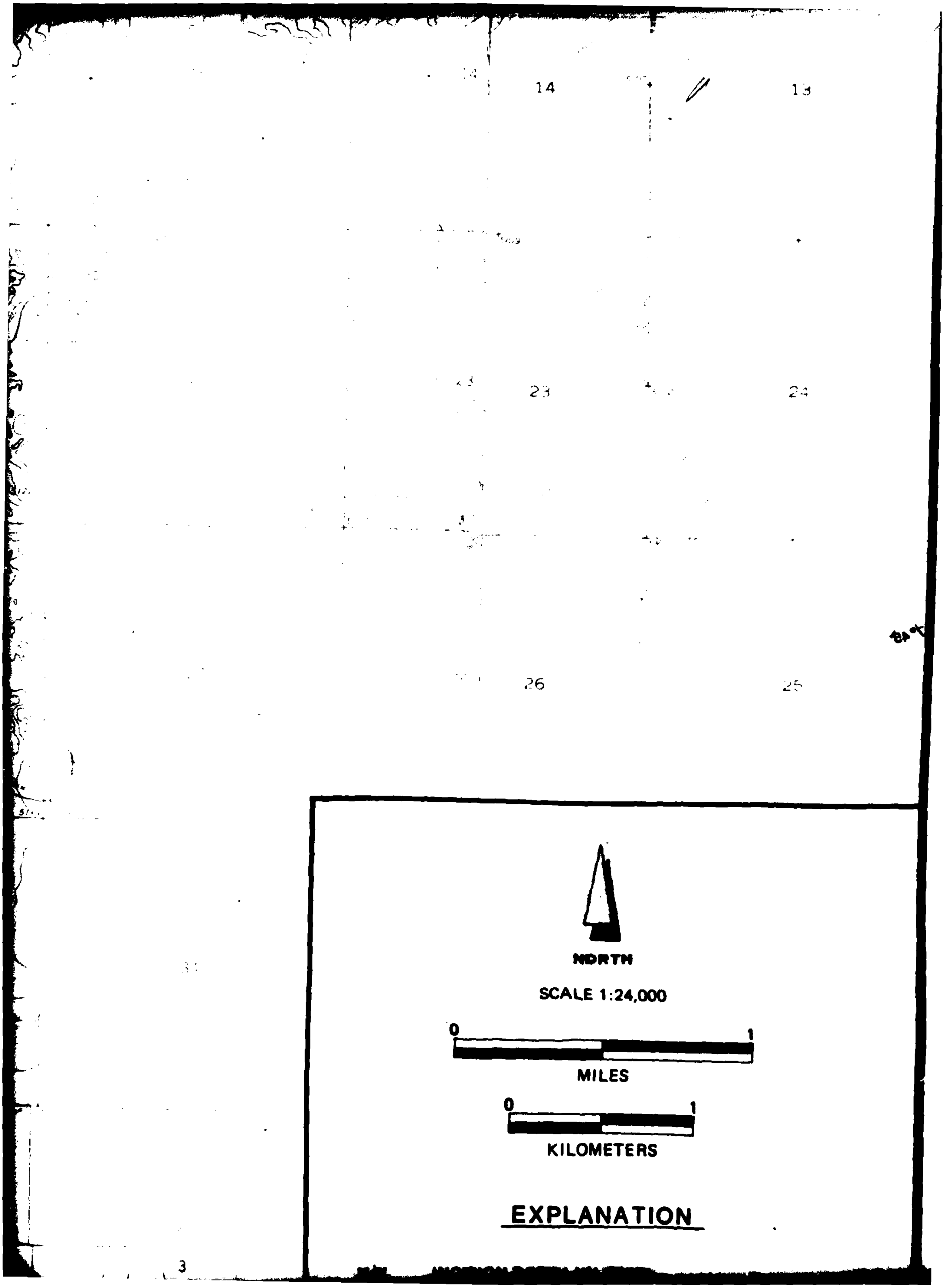
23

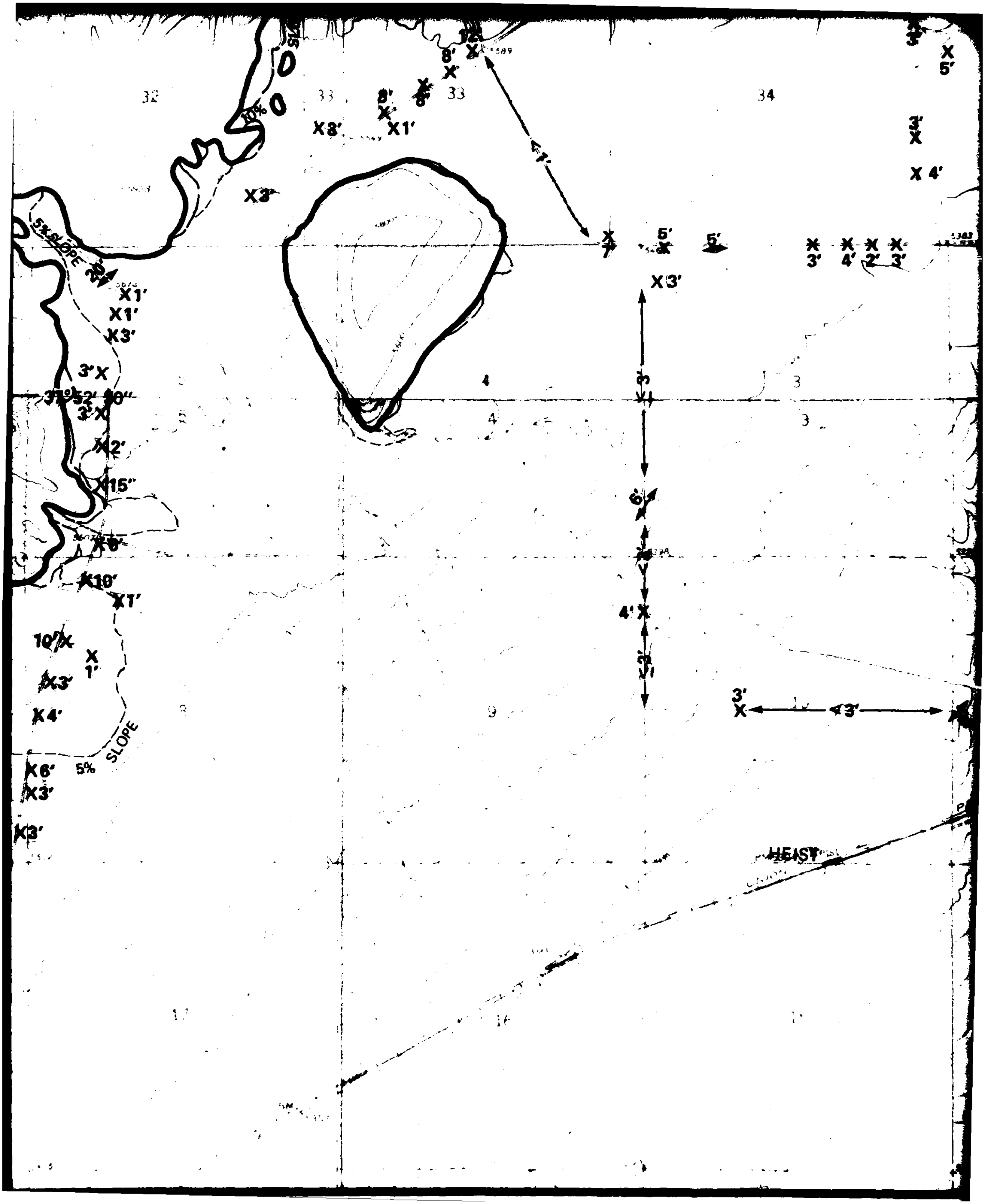
1



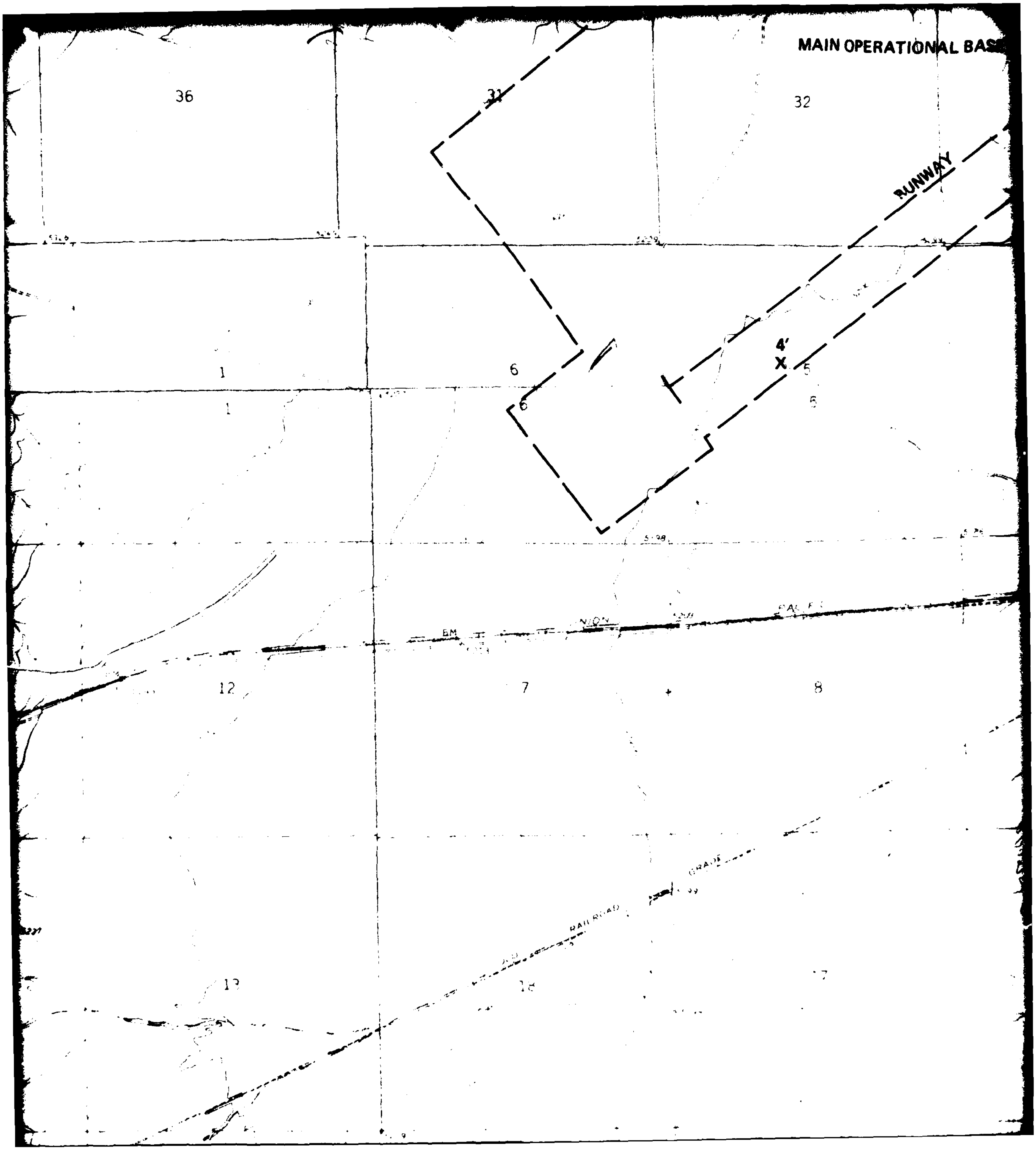
27

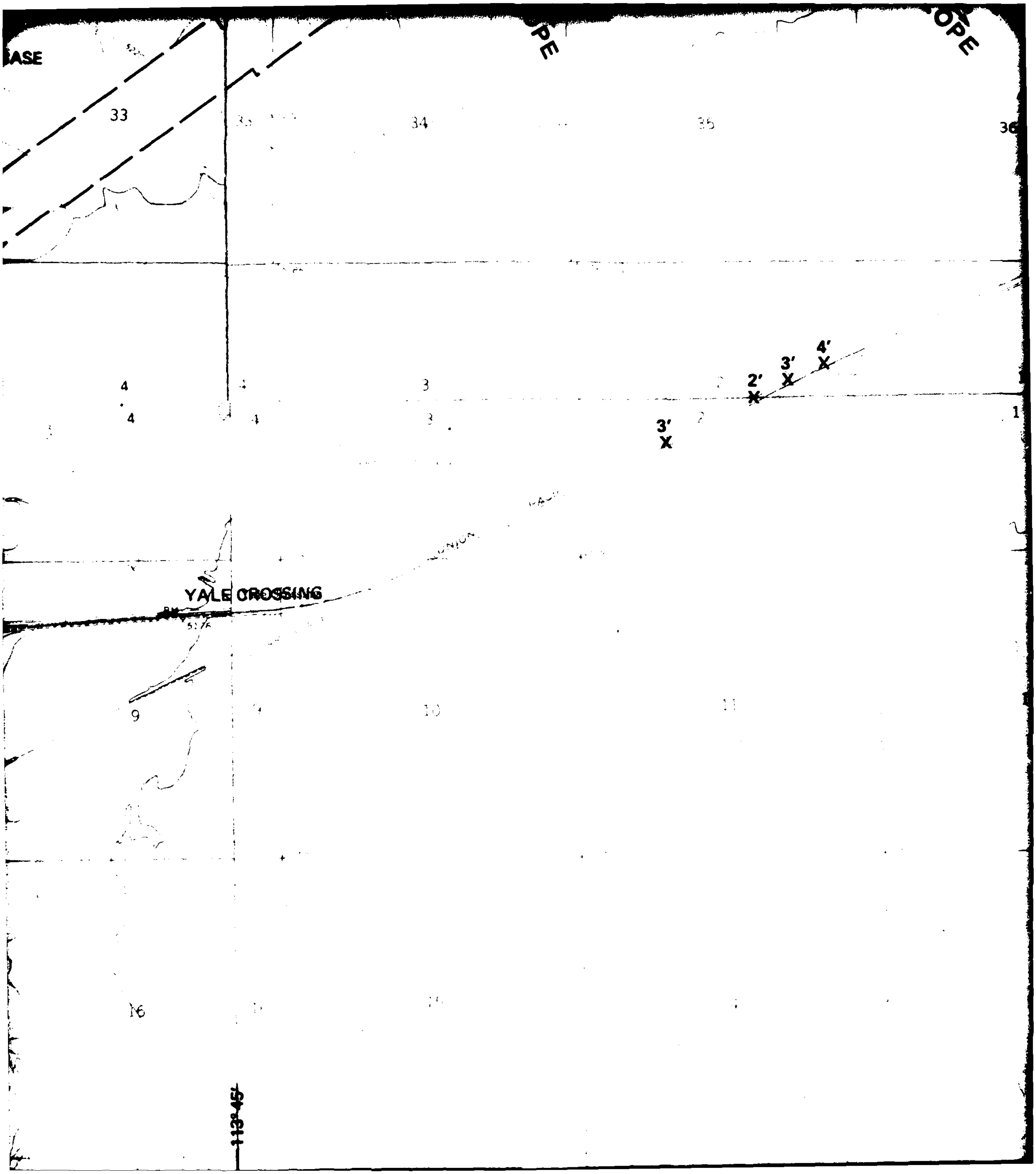
5 4

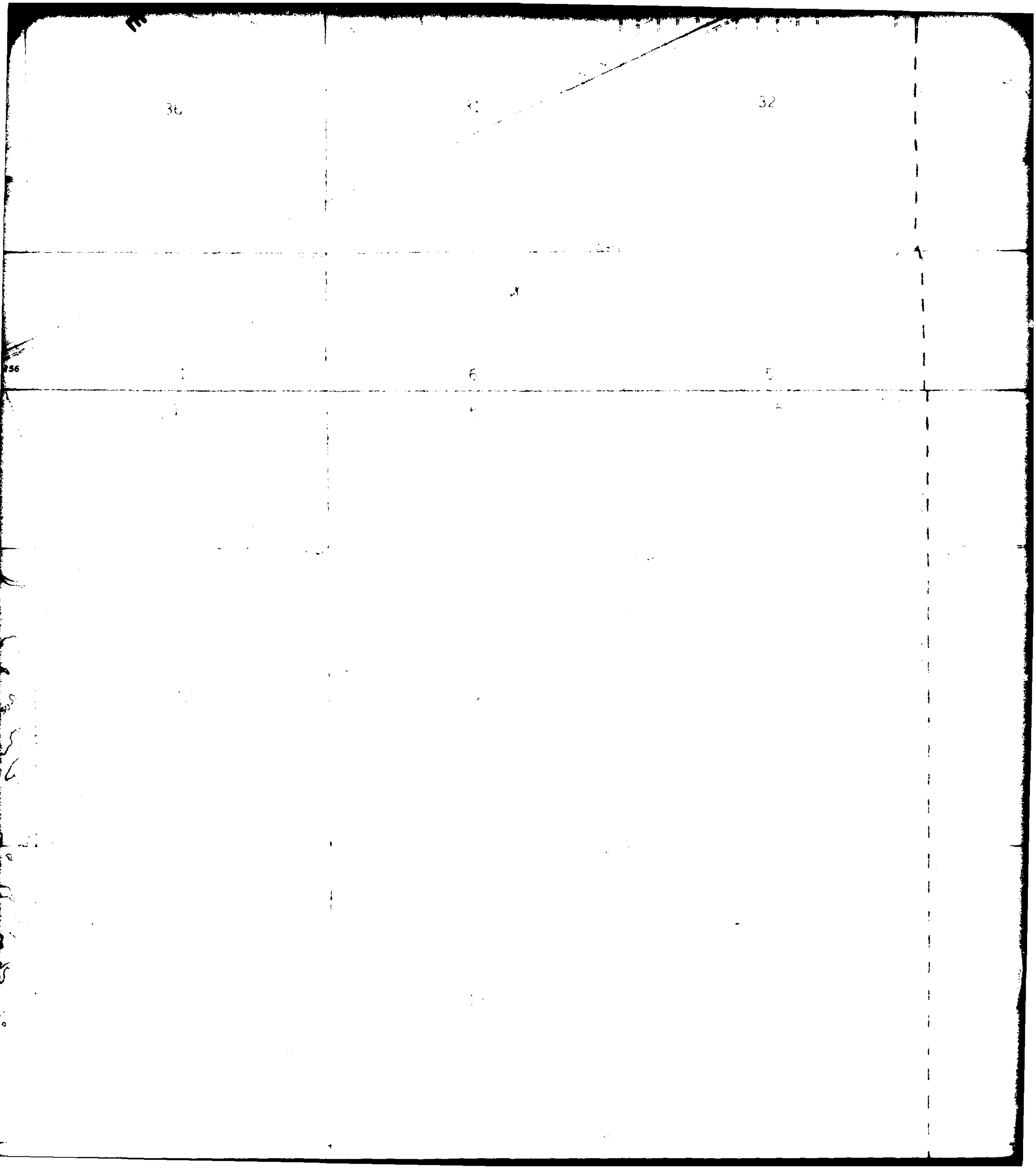

14
13
23
24
26
25
NORTH
SCALE 1:24,000
0
1
MILES
0
1
KILOMETERS
EXPLANATION
3



32
33
34
10%
X8'
X1'
X3'
5% SLOPE
X1'
X1'
X3'
3' X
3'X
X2'
X15"
X10'
X1'
10' X
X 1'
X3'
X4'
SLOPE
5%
X6'
X3'
X3'
8'
X
5'
X 5'
3' X
X 4'
X 7
5'
5'
3'
4'
2'
3'
X3'
4
3
3
6'
4' X
3' X
3'
HEISY
9
16


MAIN OPERATIONAL BAS
36
31
32
RUNWAY
1
6
4'
X
5
12
7
8
RAILROAD
GRADE


ASE
PE
OPE
33
34
35
36
4
4
3
3
2'
3'
4'
3'
1
YALE CROSSING
9
10
11
16
113°45'

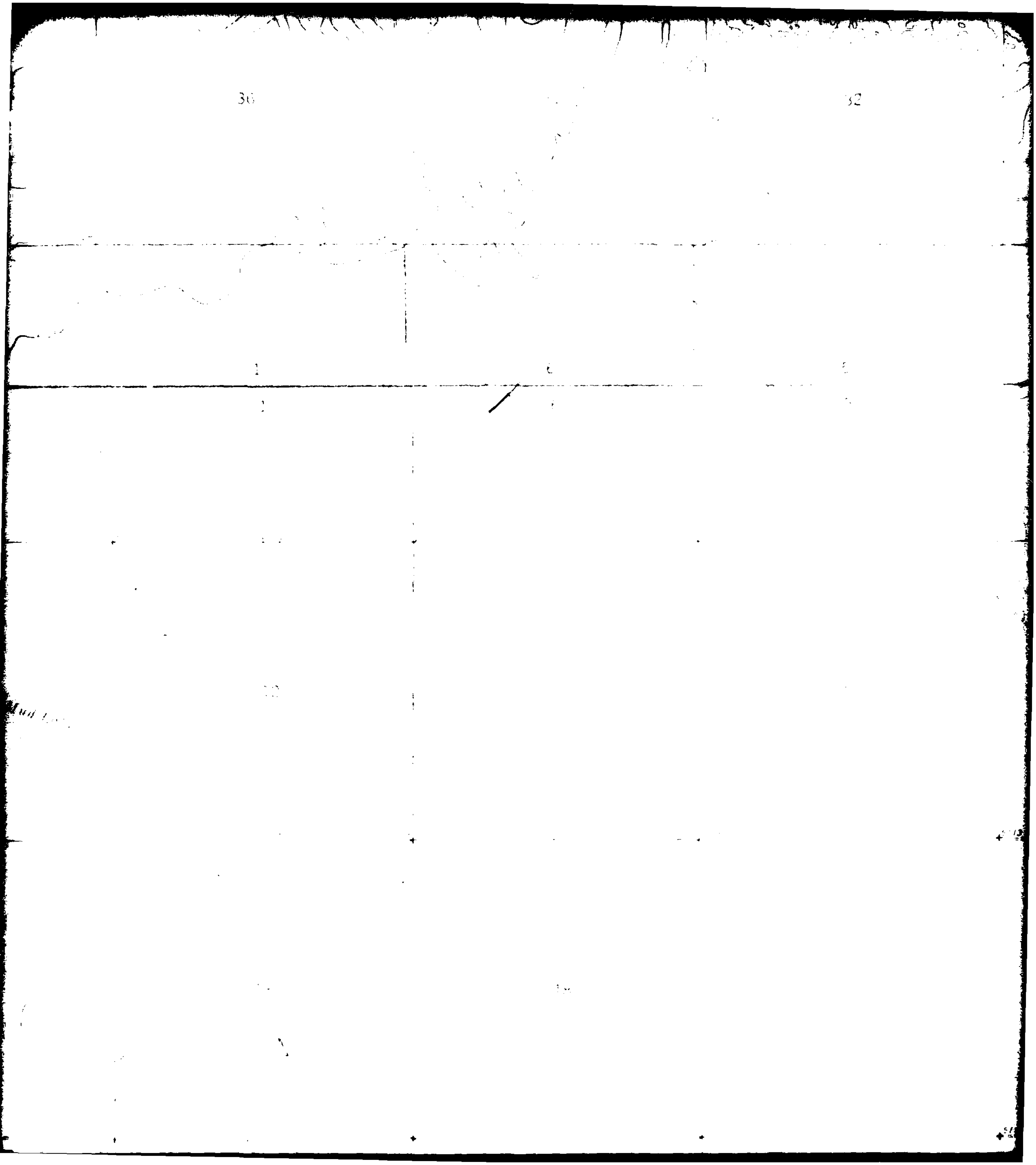

36
31
32
1
6
5

33 4 4

4 3

3

10


36
32

NORTH

SCALE 1:24,000

0

MILES

0 1

KILOMETERS

EXPLANATION

X 5' INCISION DEPTH (IN FEET)

10' INCISION WIDTH (NUMBER INDICAT

8% SLOPE LOCAL SURFACE SLOPE; ARROW PO

DELINEATES AREAS OF ≥5% and <1

DELINEATES AREAS OF ≥10% slope

DELINEATES AREAS WITH 3 OR MOR
≥10 FEET DEEP PER 1000 FEET

CONTACT BETWEEN BEDROCK AND

PROPOSED ACTIVITY CENTER BOUN
(APPROXIMATELY LOCATED)

NOTE: DEPTHS FOR ONLY A REPRESENTATIV
INCISIONS ARE SHOWN.

TERRAIN MAP
OPERATIONAL BASE S
BERYL, UTAH

MX SITING INVESTIGATION

DEPARTMENT OF THE AIR FORCE – BMO

FUGRO NATION

NORTH

SCALE 1:24,000

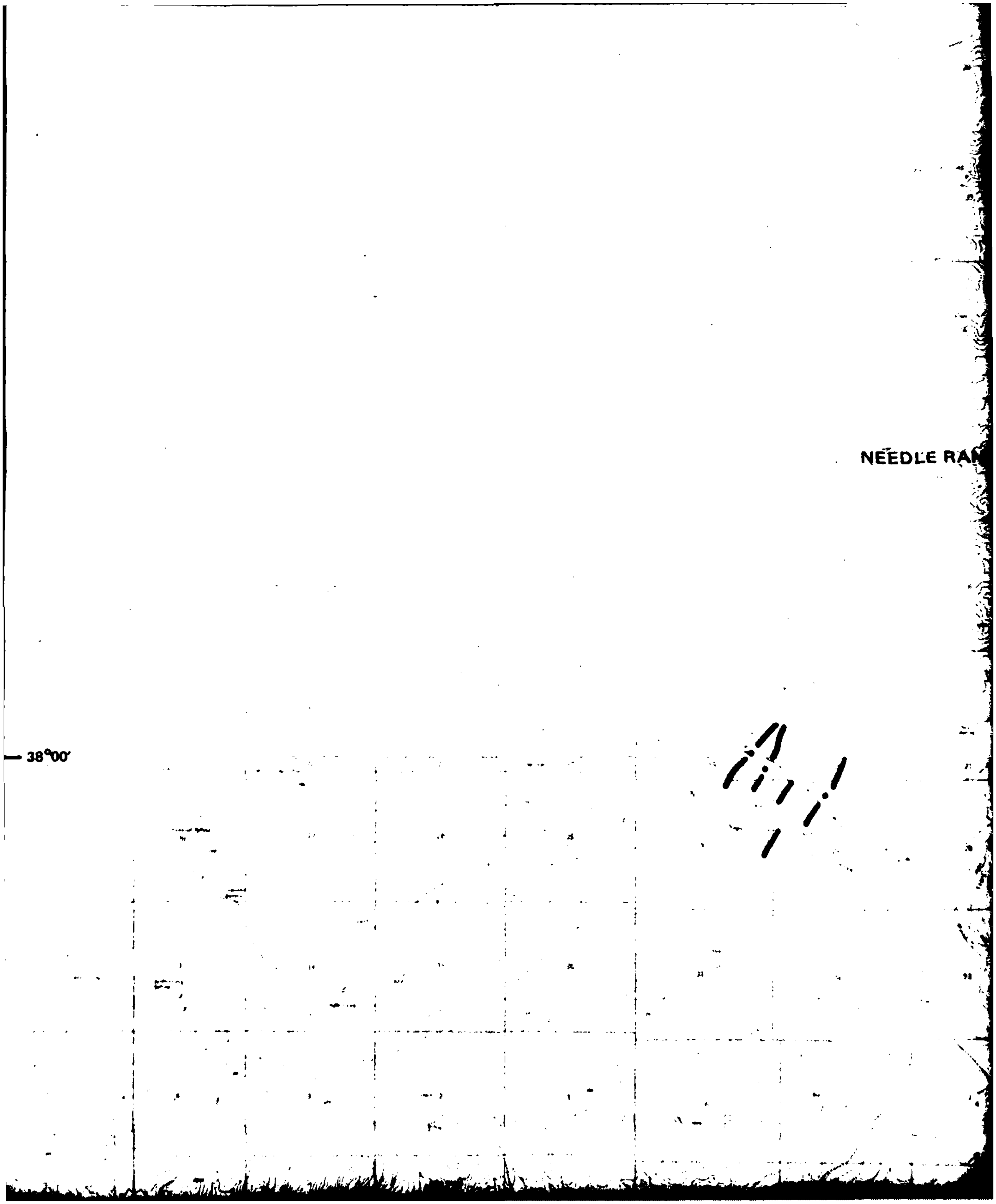
MILES

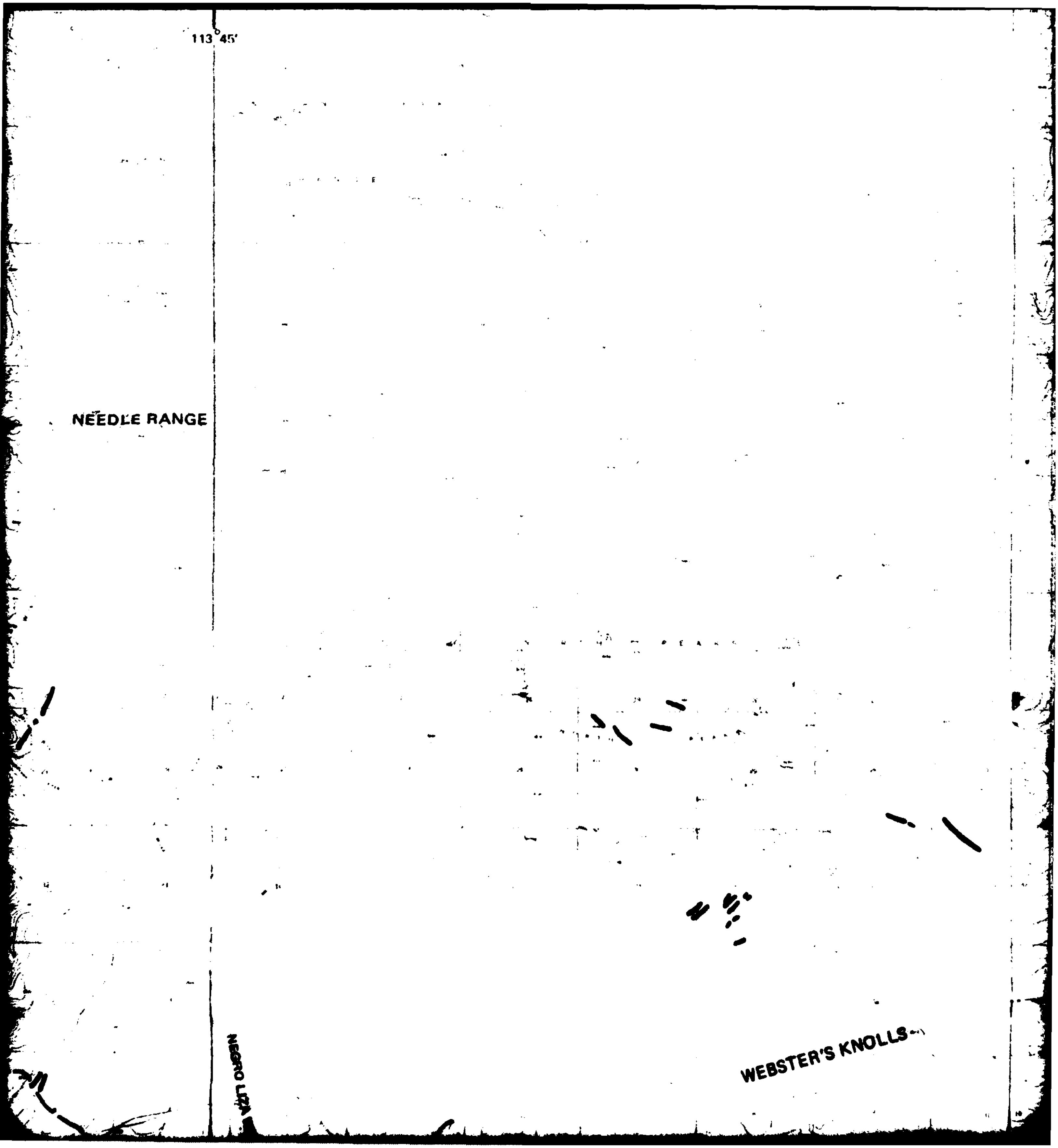
KILOMETERS

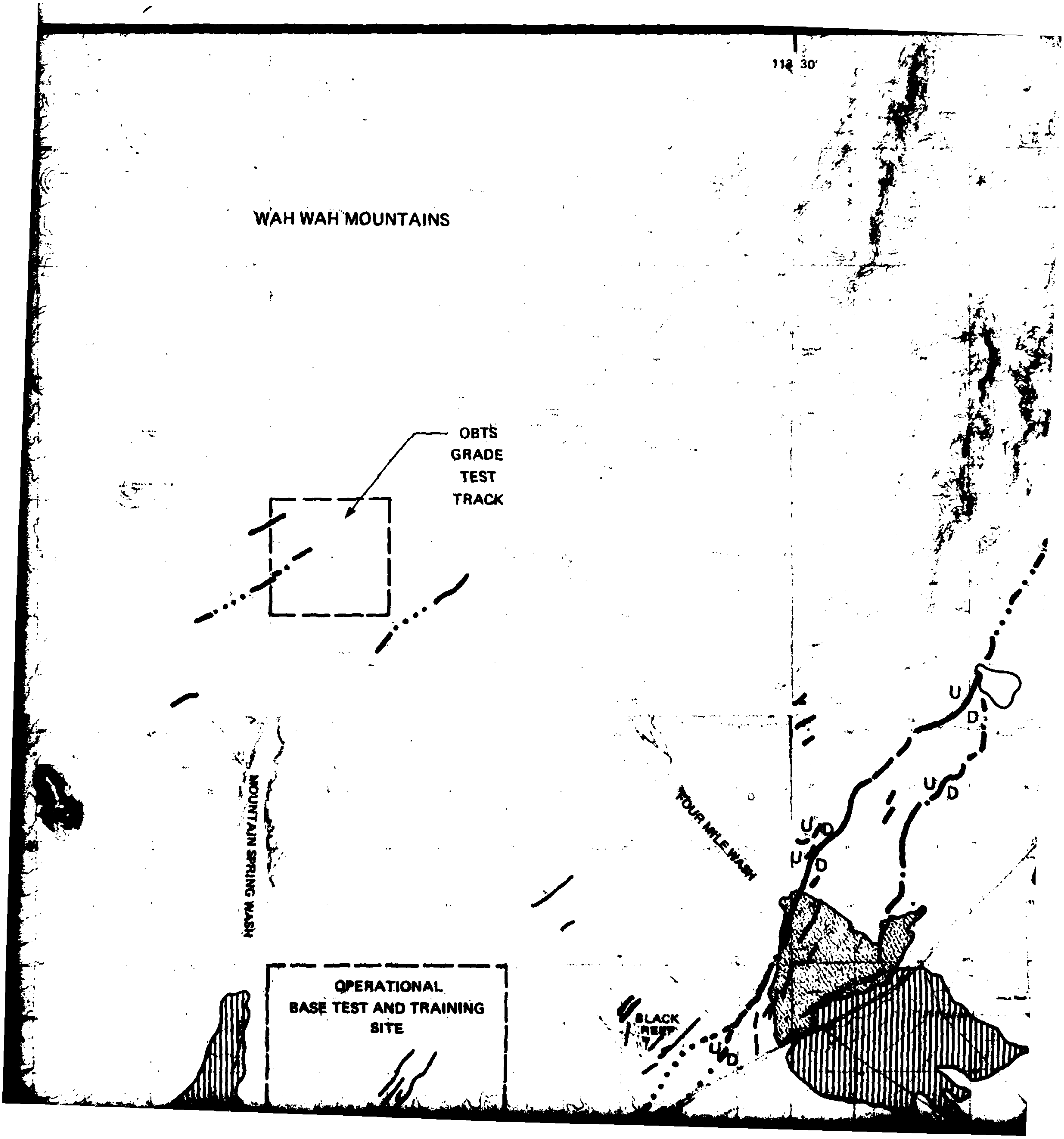
EXPLANATION

X 5′	INCISION DEPTH (IN FEET)
←10′→	INCISION WIDTH (NUMBER INDICATES INCISION DEPTH)
8% → SLOPE	LOCAL SURFACE SLOPE; ARROW POINTS DOWNSLOPE
- - - - - - -	DELINEATES AREAS OF $\geq$5% and < 10% slope
— — —	DELINEATES AREAS OF $\geq$ 10% slope
————	DELINEATES AREAS WITH 3 OR MORE DRAINAGES $\geq$10 FEET DEEP PER 1000 FEET
━━━━	CONTACT BETWEEN BEDROCK AND BASIN FILL UNITS
┌ ─ ─ ┐ └ ─ ─ ┘	PROPOSED ACTIVITY CENTER BOUNDARIES (APPROXIMATELY LOCATED)

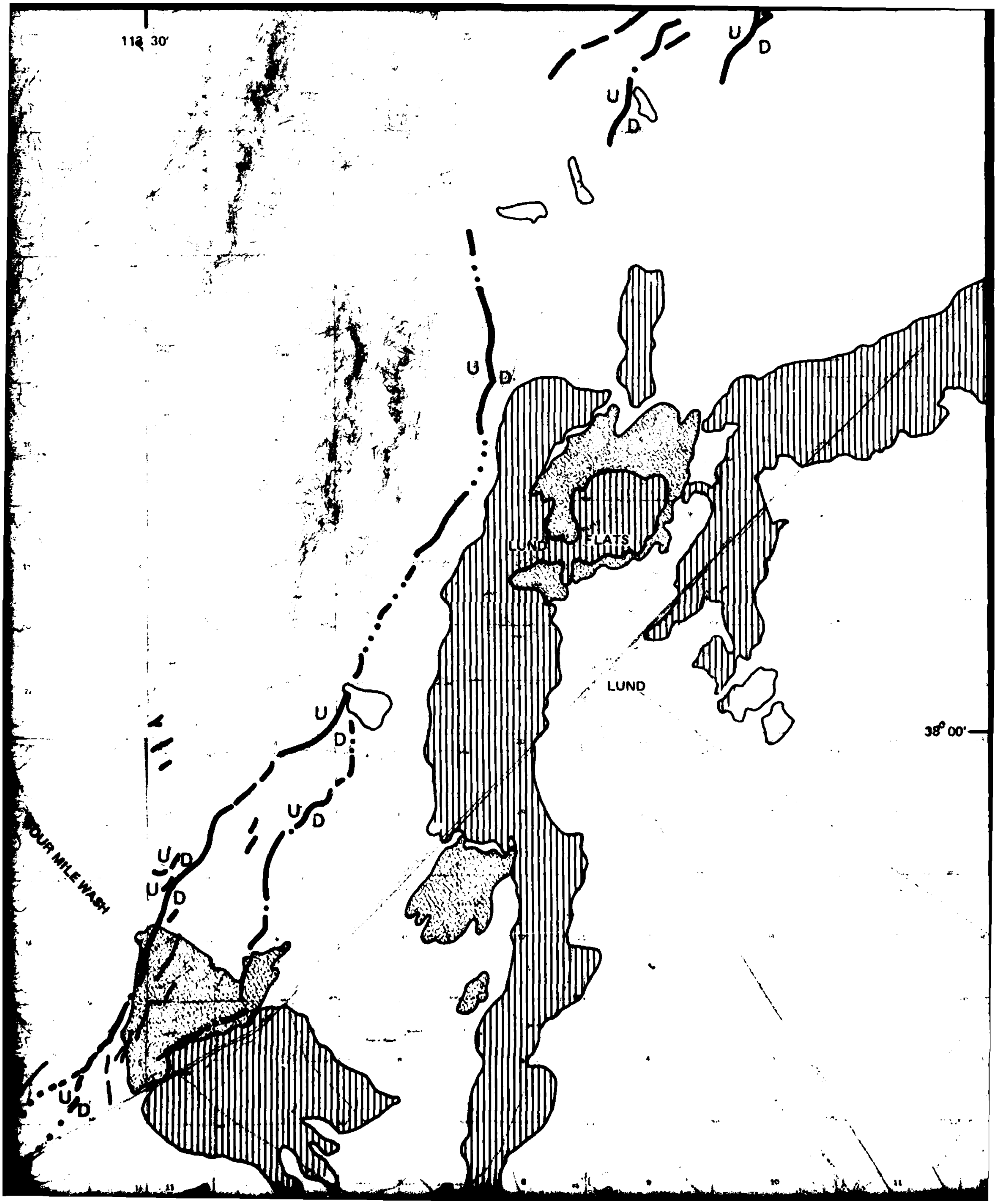
NOTE: DEPTHS FOR ONLY A REPRESENTATIVE SAMPLING OF INCISIONS ARE SHOWN.

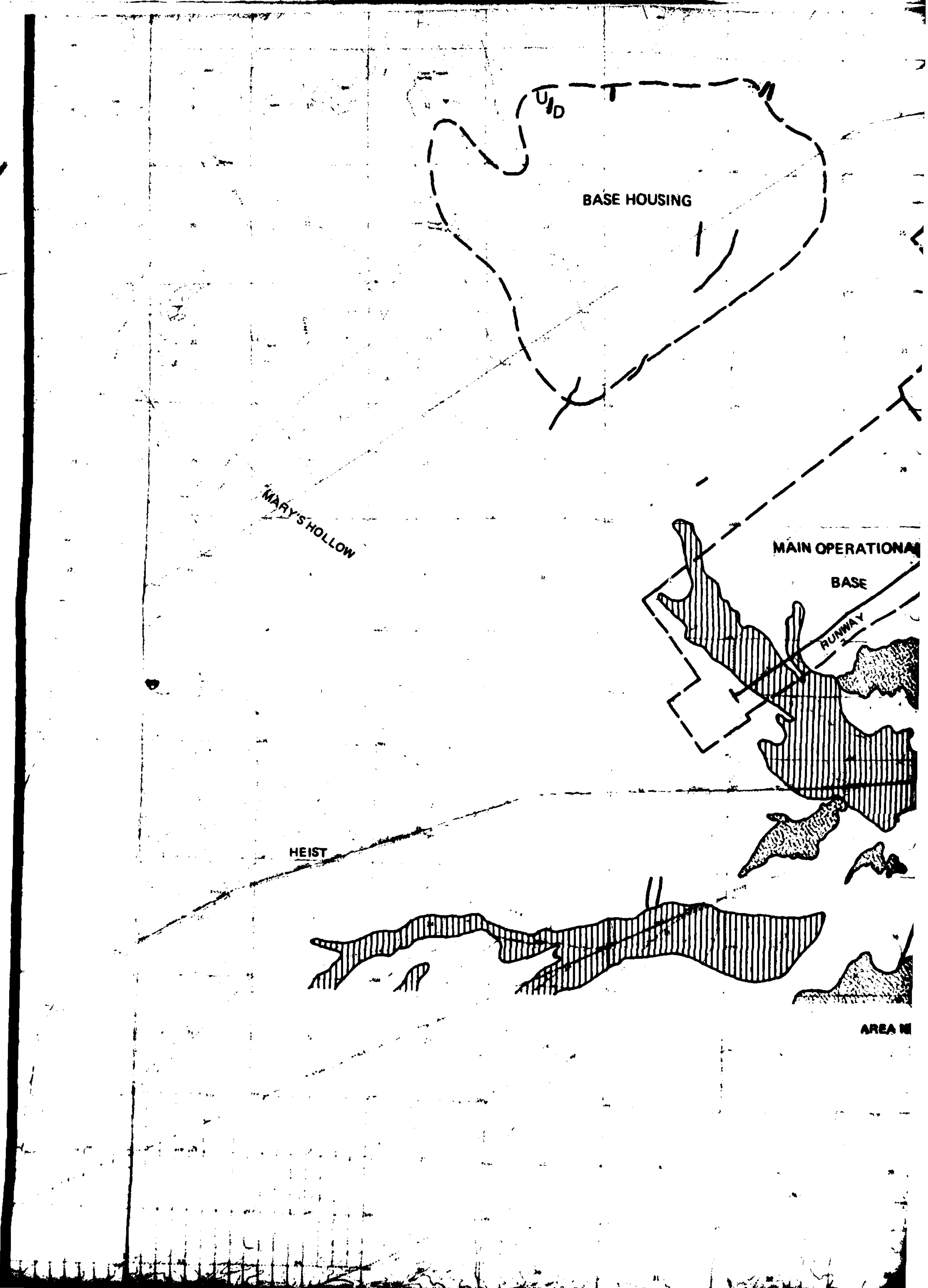

NEEDLE RA
38°00'

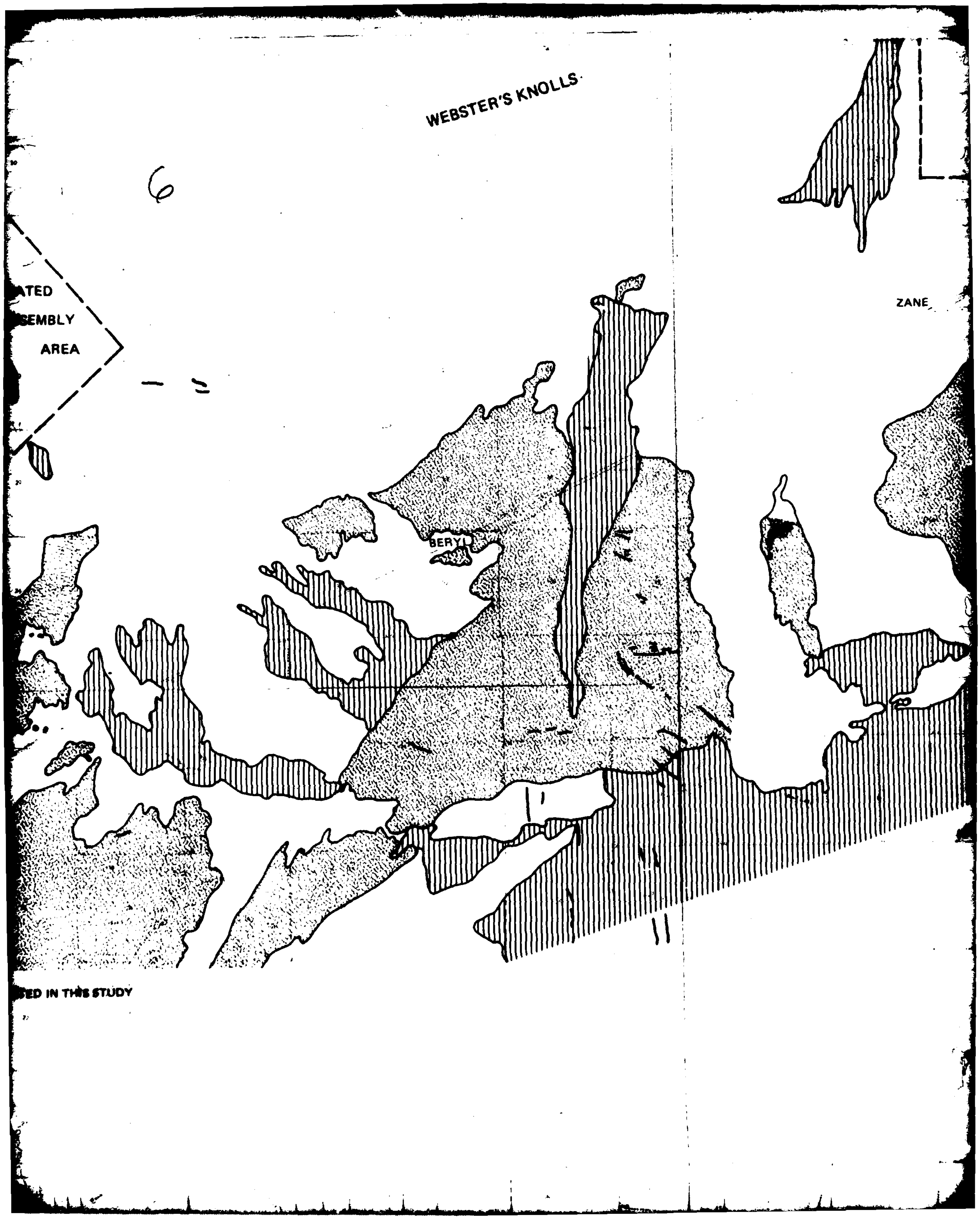

113°45'
NEEDLE RANGE
NEGRO LIZA
WEBSTER'S KNOLLS

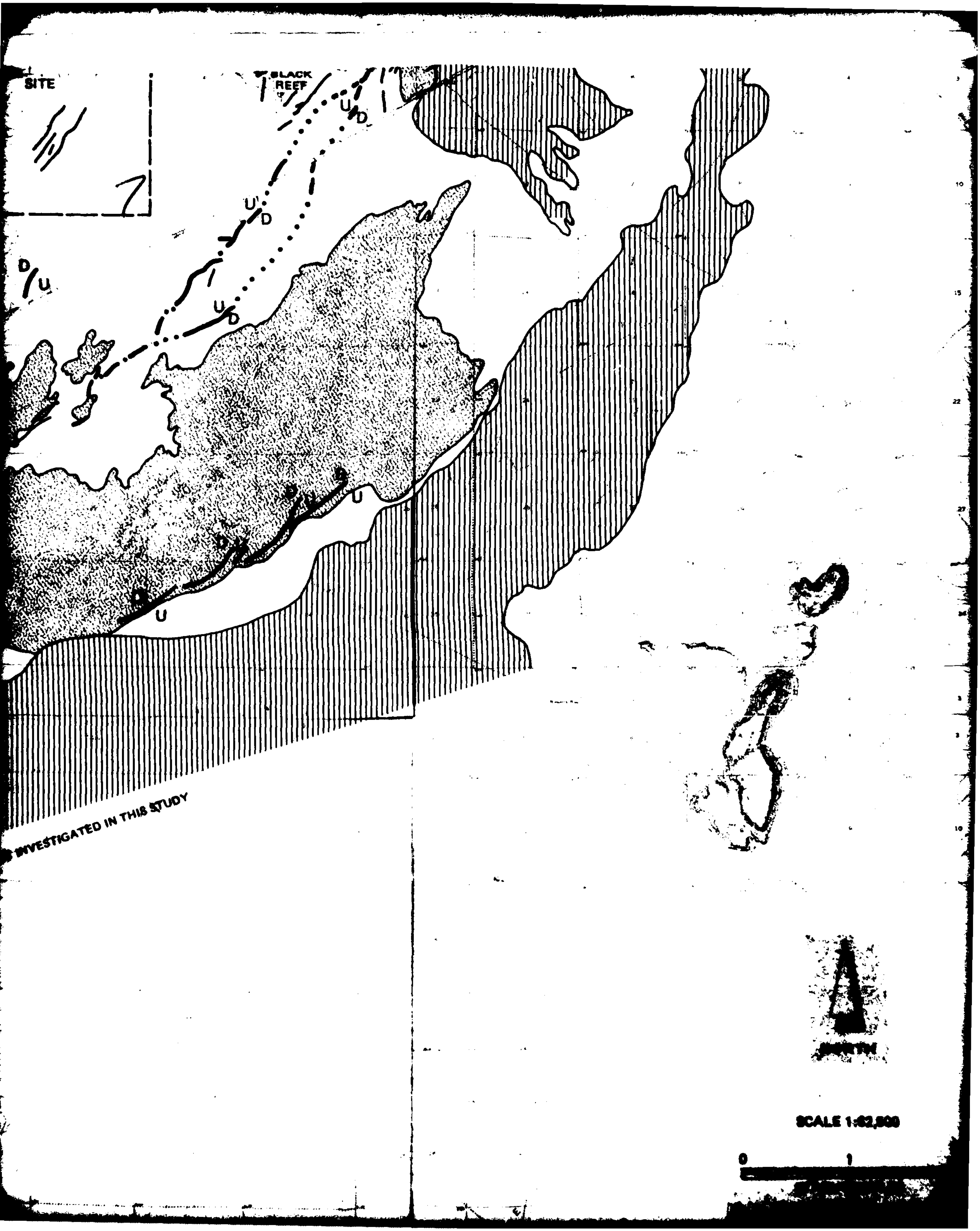


113 30'
WAH WAH MOUNTAINS
OBTS
GRADE
TEST
TRACK
MOUNTAIN SPRING WASH
FOUR MILE WASH
U
D
OPERATIONAL
BASE TEST AND TRAINING
SITE
BLACK
REEF

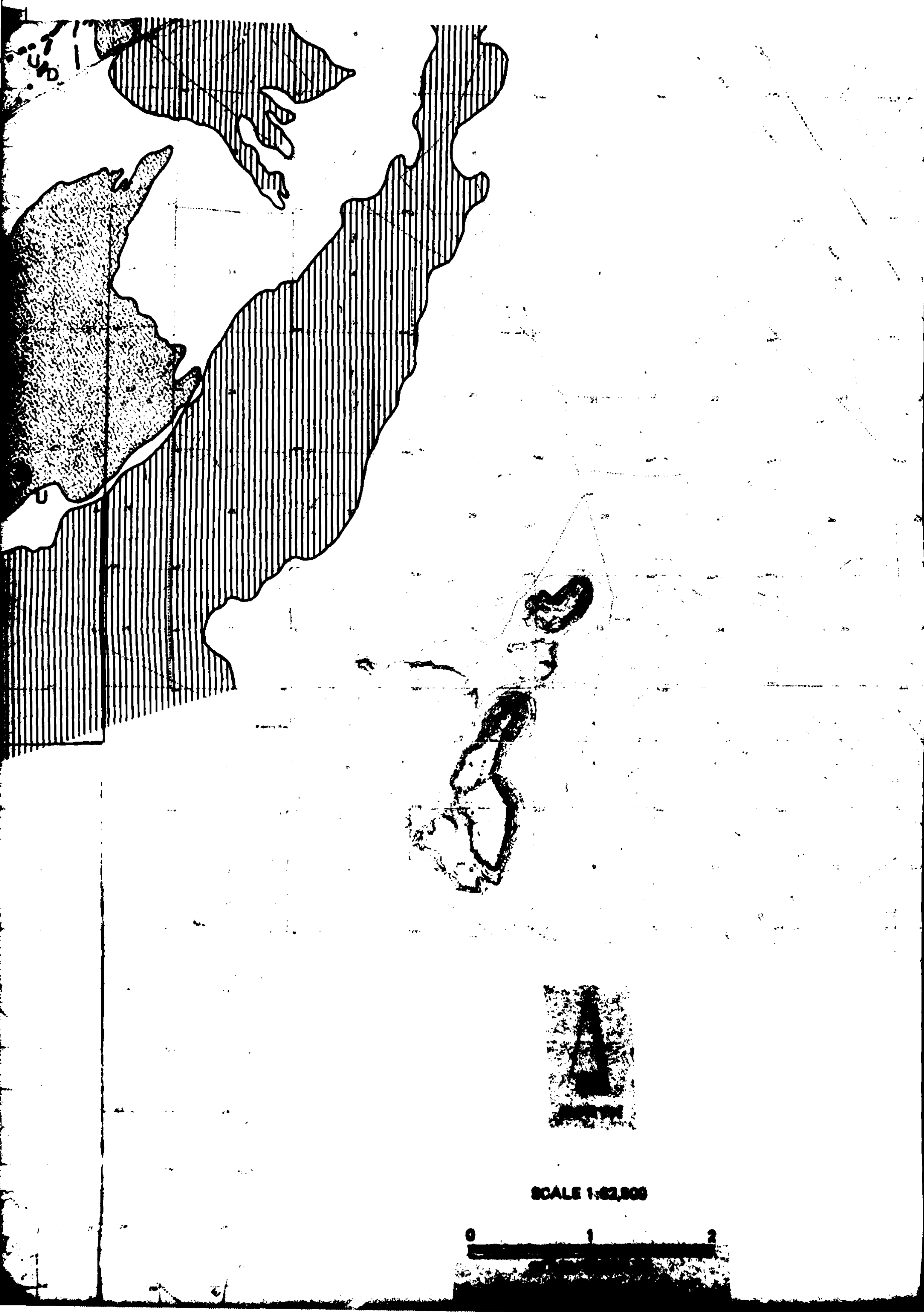

113 30'
U
D
U
D
U
D
LUND FLATS
LUND
38° 00'
U
D
U
D
FOUR MILE WASH
U
D
U
D
U
D


BASE HOUSING
MARY'S HOLLOW
BASE
RUNWAY
HEIST

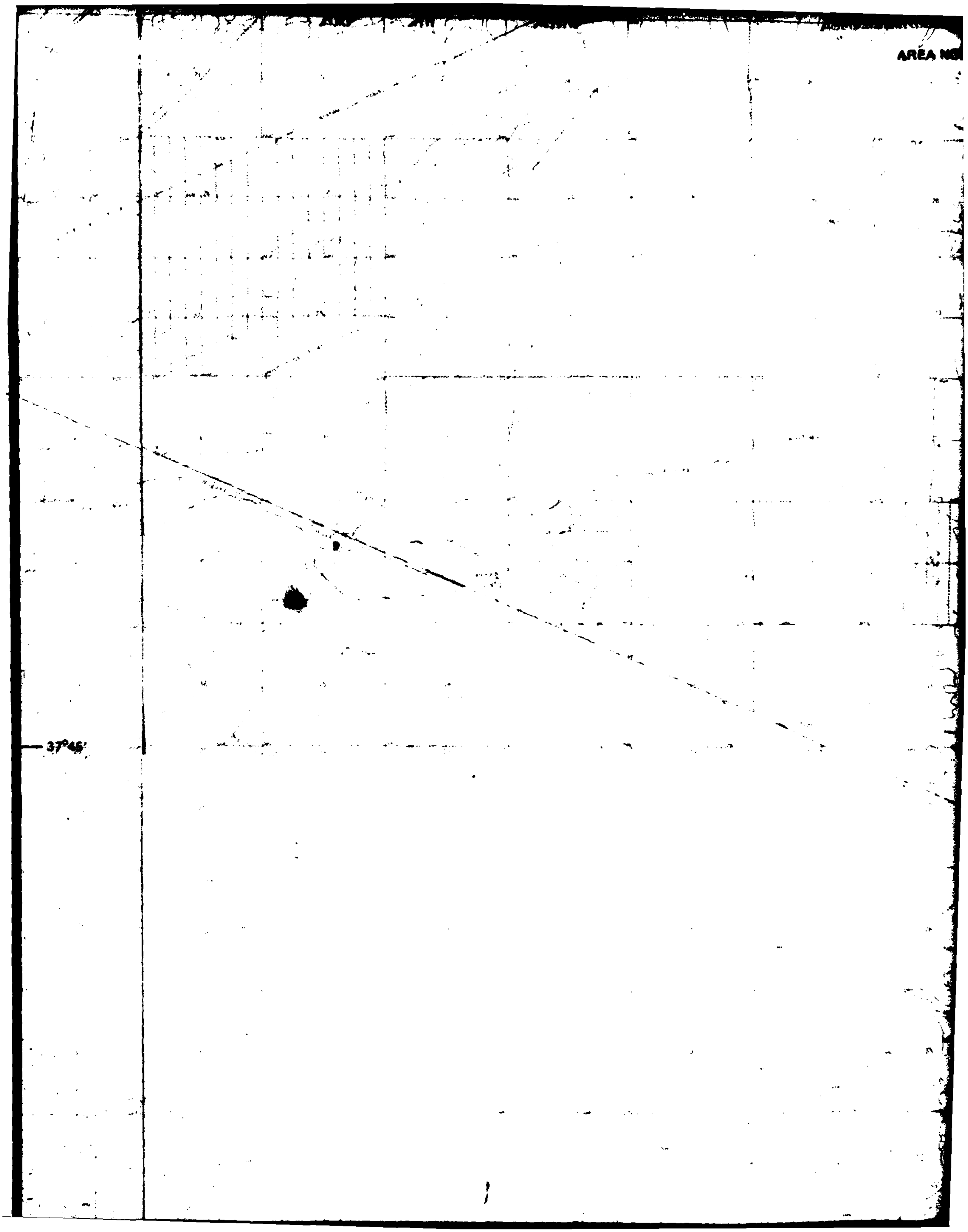

WEBSTER'S KNOLLS
6
ATED
SEMBLY
AREA
BERYL
ZANE
ED IN THIS STUDY



SITE
BLACK REEF
U D
U D
D U
U D
U
U
INVESTIGATED IN THIS STUDY
NORTH
SCALE 1:62,500
0 1

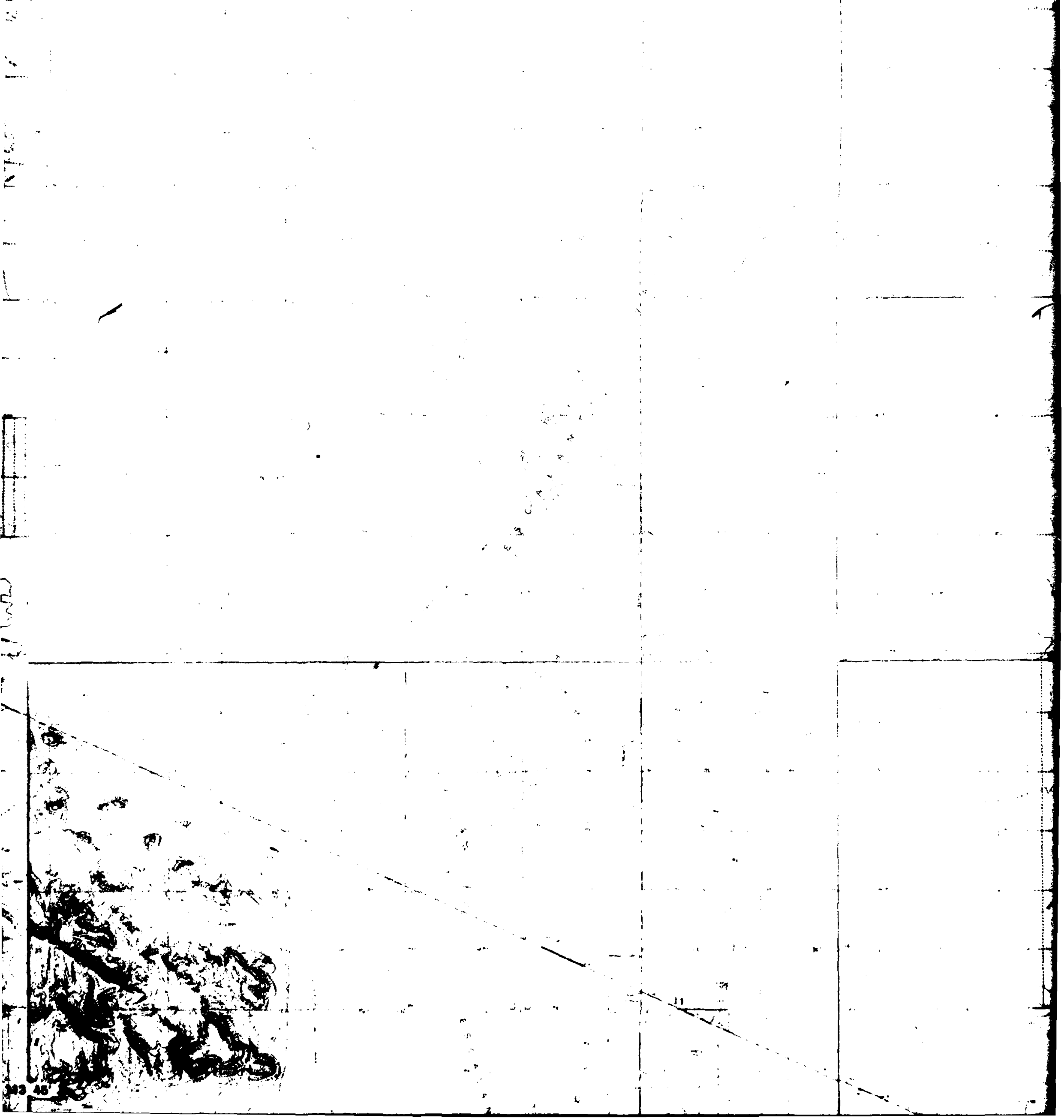


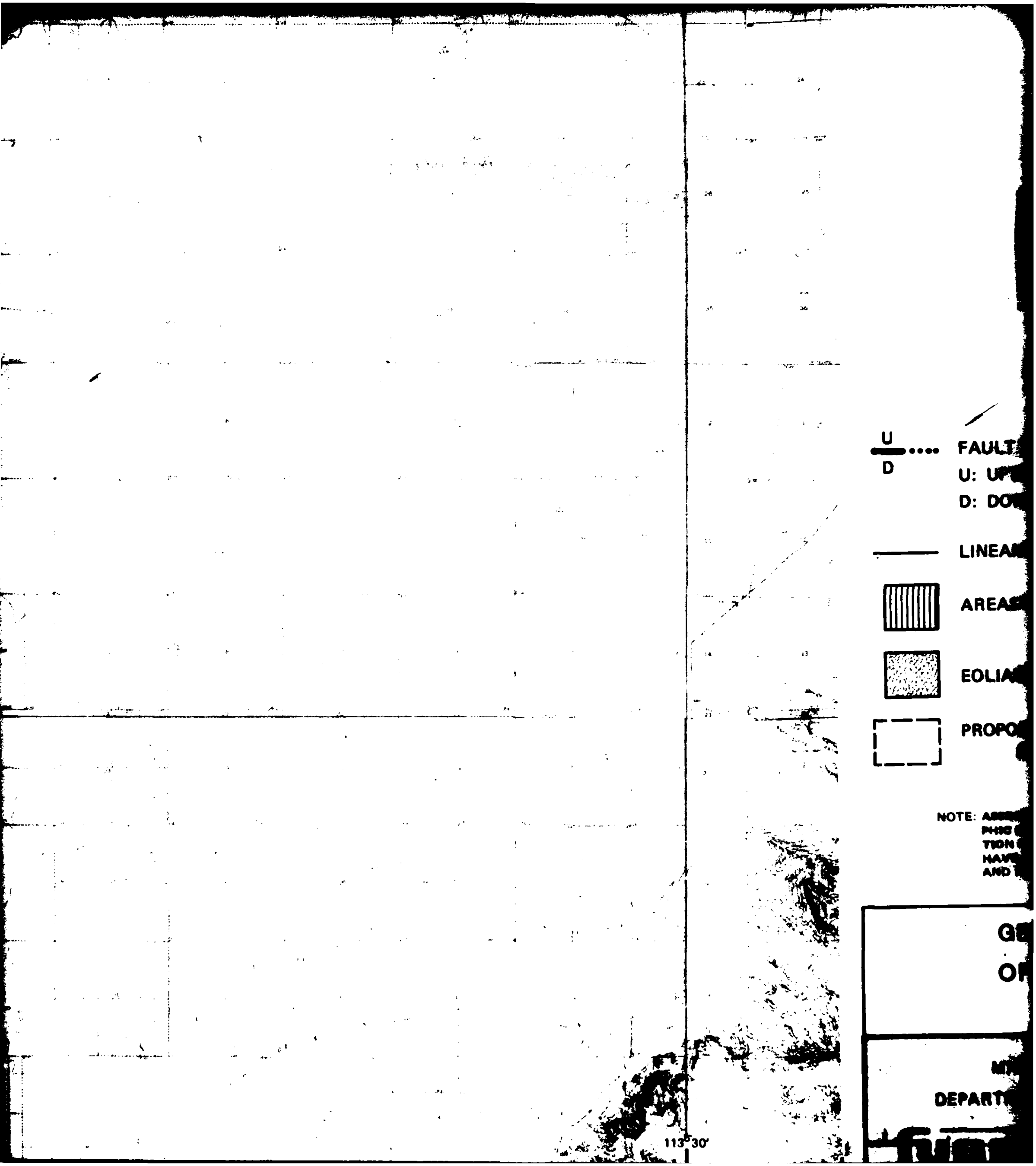
8



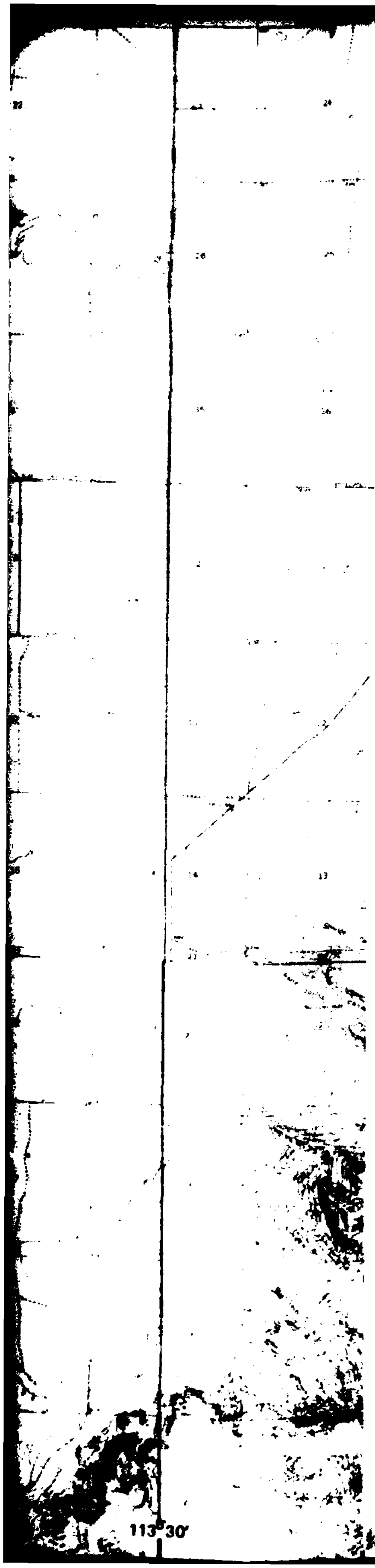
AREA
37°45'

OT INVESTIGATED IN THIS STUDY





U
D
FAULT
U: UP
D: DO
LINEA
AREAS
EOLIA
PROPO
NOTE:
GE
OF
DEPART
113°30'



SCALE 1:62,500

0 1 2
STATUTE MILES

0 1 2
KILOMETERS

EXPLANATION

U / D FAULT TRACE; DOTTED WHERE INFERRED
U: UPTHROWN BLOCK
D: DOWNTHROWN BLOCK

LINEAMENTS

AREAS SUBJECT TO FLOODING

EOLIAN DEPOSITS

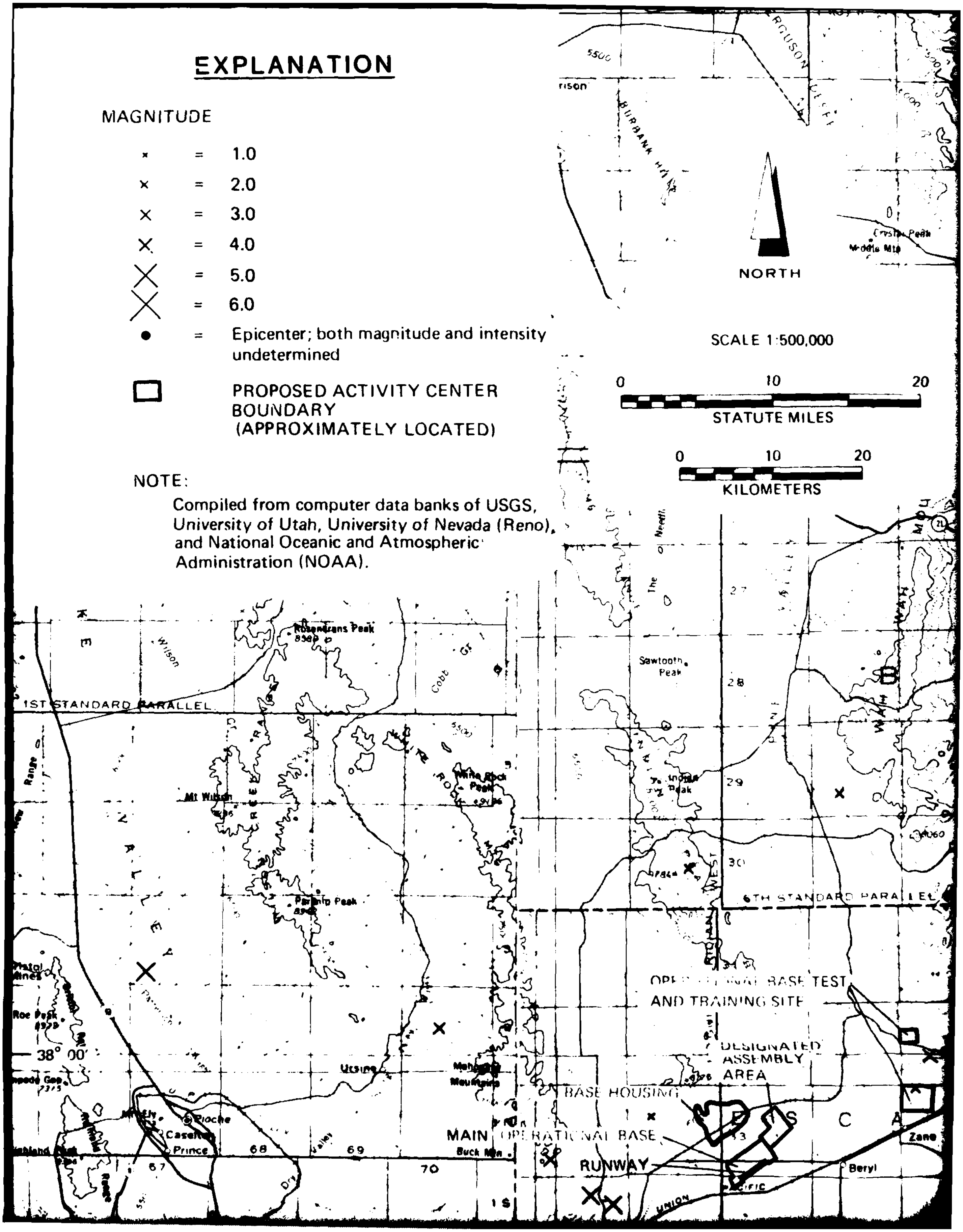
PROPOSED ACTIVITY CENTER BOUNDARY (APPROXIMATELY LOCATED)

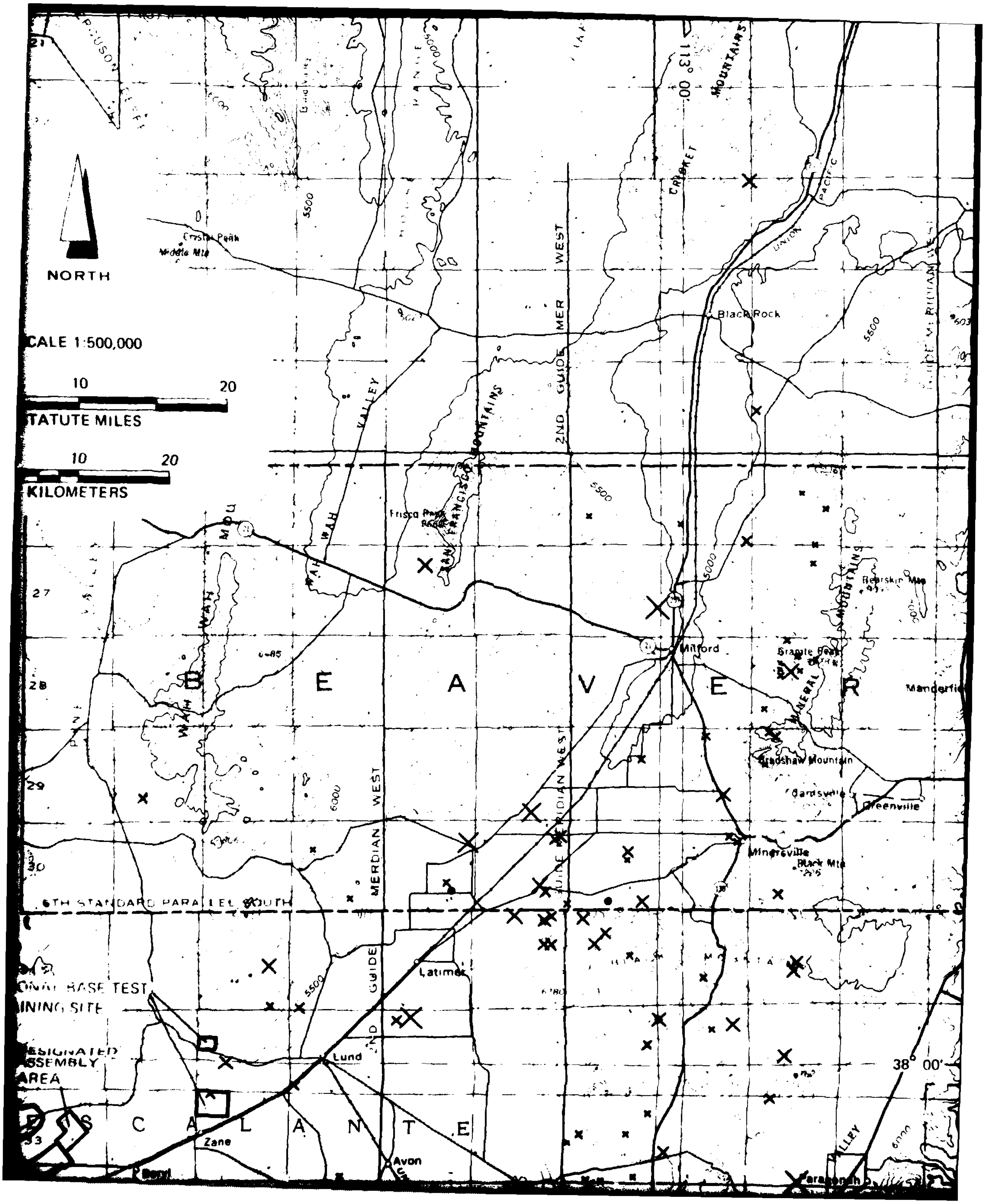
NOTE: ASSESSMENT OF FLOOD POTENTIAL IS BASED ON GEOMORPHIC FEATURES THAT WERE FORMED PRIOR TO CONSTRUCTION OF THE RAILROAD TRACKS AND THE ROADS AND HAVE BEEN ALTERED IN SOME AREAS SINCE THE ROADS AND RAILROAD TRACKS WERE BUILT.

GEOLOGIC HAZARDS MAP
OPERATIONAL BASE SITE
BERYL, UTAH

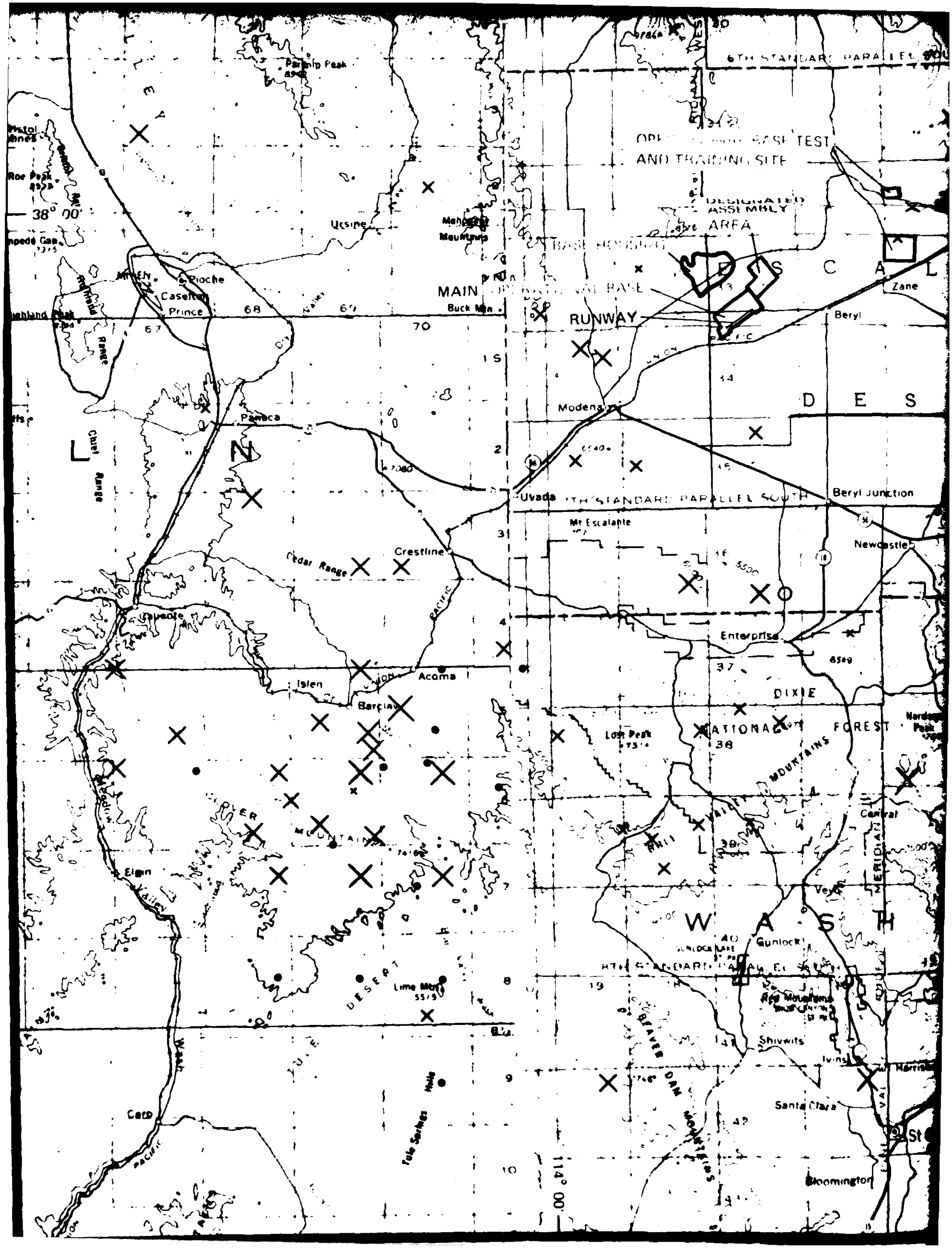
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE – BMO	DRAWING 5-4

FUGRO NATIONAL, INC.

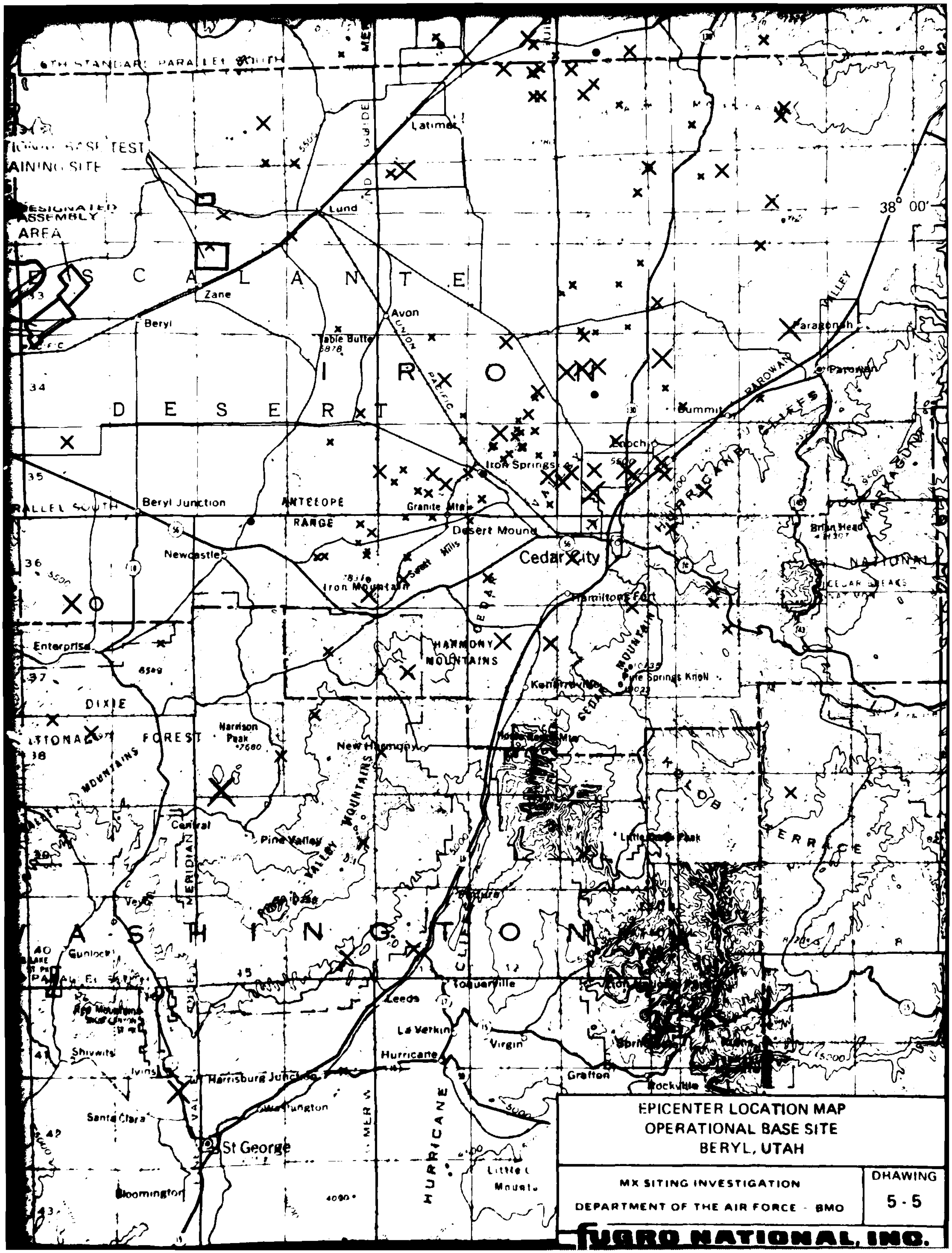

EXPLANATION
MAGNITUDE
= 1.0
= 2.0
= 3.0
= 4.0
= 5.0
= 6.0
= Epicenter; both magnitude and intensity undetermined
PROPOSED ACTIVITY CENTER BOUNDARY (APPROXIMATELY LOCATED)
NOTE:
Compiled from computer data banks of USGS, University of Utah, University of Nevada (Reno), and National Oceanic and Atmospheric Administration (NOAA).
NORTH
SCALE 1:500,000
0 10 20
STATUTE MILES
0 10 20
KILOMETERS
1ST STANDARD PARALLEL
6TH STANDARD PARALLEL
Rosencrans Peak
Sawtooth Peak
Mt Wilson
White Rock Peak
Parsnip Peak
38° 00'
Roe Peak
Pioche
Caselton
Prince
Ursine
Mahogany Mountains
Buck Mtn
Crystal Peak
Middle Mtn
Indian Peak
BASE HOUSING
DESIGNATED ASSEMBLY AREA
AND TRAINING SITE
MAIN
RUNWAY
Beryl
Zane
UNION



NORTH
CALE 1:500,000
10
20
TATUTE MILES
10
20
KILOMETERS
113° 00'
CRICKET
MOUNTAINS
UNION PACIFIC
Black Rock
2ND GUIDE MER WEST
SAN FRANCISCO MOUNTAINS
Frisco Peak
WAH WAH VALLEY
WAH WAH MOU
Milford
Beaver
MINERAL MOUNTAINS
Granite Peak
Bradshaw Mountain
Greenville
Minersville
Black Mtn
B E A V E R
Manderfie
MERIDIAN WEST
6TH STANDARD PARALLEL SOUTH
Latimer
Lund
Zane
Avon
Beryl
E S C A L A N T E
38° 00'
VALLEY
Paragonah
DESIGNATED ASSEMBLY AREA
5500
6000
5000
27
28
29
30
33



6TH STANDARD PARALLEL SOU
AND TRAINING SITE
DESIGNATED ASSEMBLY AREA
BASE HOUSING
MAIN
RUNWAY
Parsnip Peak
Pistol Pines
Roe Peak
38° 00'
Ursine
Pioche
Caselton
Prince
Buck Mtn
Zane
Beryl
Modena
Panaca
Uvada
Beryl Junction
Mt Escalante
Crestline
Cedar Range
Newcastle
Enterprise
Caliente
Islen
Acoma
Barclay
DIXIE
NATIONAL
FOREST
Lost Peak
MOUNTAINS
CLOVER
MOUNTAINS
Elgin
Central
Veyo
Gunlock
Lime Mtn
DESERT
Shivwits
Ivins
Santa Clara
BEAVER DAM
MOUNTAINS
Tule Springs
Caro
Bloomington
114° 00'
L
N
S
C
A
L
D
E
S
W
A
S
H



EPICENTER LOCATION MAP
OPERATIONAL BASE SITE
BERYL, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

DRAWING 5-5